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The Academy will meet on Monday evenings at 8.15 o'clock, from October 7th to May 19th, in the rooms of the Chemist's Club, **108 West 55th Street.**

* Deceased.

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REPORT ON THE HEXACTINIÆ OF THE COLUMBIA UNIVERSITY EXPEDITION TO PUGET SOUND DURING THE SUMMER OF 1896

J. Playfair McMurrich

[Plates I–III; text figures I–II.]

(Read November 14, 1898)

In presenting this report I must testify to the pleasure I experienced in studying the collection, a pleasure due both to the admirable preservation of all the specimens and to the careful notes and drawings which accompanied them. The credit for both belongs to Dr. Gary N. Calkins. The method employed for the preservation was a preliminary immersion in magnesium sulphate as suggested by Tullberg, followed by fixation and preservation in formalin. Nearly all the specimens were beautifully expanded and the histological preservation was excellent. The only disadvantage presented by the method, probably due to the formalin, was the failure of preparations to stain with the ordinary carmine stains, such as Grenacher's borax carmine; hæmatoxylin stains acted admirably, however.

I wish also to express my thanks to Mr. Alexander Agassiz for his kindness in loaning me, for comparison, a number of drawings of West Coast forms prepared from livings specimens several years ago.

The manuscript of this paper was originally completed in April, 1898, but I have taken advantage of the long delay which has occurred in its publication to introduce some references to papers which have appeared more recently, and also to correct a grievous misapprehension into which I had fallen with regard to the systematic position of *Epiactis prolifera*. The nature of this misapprehension is explained in the description of the species.

HEXACTINIÆ

Actininæ

Family SAGARTIIDÆ

Actininæ with adherent base; with a mesoglœal (rarely a weak endodermal sphincter); and with acontia which are emitted either through the mouth alone or also through special openings (cinclides) in the column wall.

The family Sagartiidæ, since its first establishment by Gosse in 1858, has undergone certain changes which have for the most part been fully discussed by various authors. Within recent years there has been introduced a subdivision into subfamilies. The family Phellinæ of Verrill ('68) has been added as a subfamily and the remaining forms assigned to the subfamilies Sagartiinæ or Metridiinæ according as they possessed more than six pairs of perfect mesenteries or only that number (Carlgren '93); a subfamily Chondractininæ had previously been proposed by Haddon ('89); Simon ('92), recognized two subfamilies Aiptasiinæ and Sagartiinæ, the former characterized by possessing an endodermal sphincter or none at all; and, finally, Haddon accepts all the proposed subdivisions, admitting the existence of no less than five subfamilies.

It seems to me that the subdivision proposed by Carlgren is that to be preferred. I do not think the recognition of a subfamily Aiptasiinæ is advisable since several undoubted Aiptasias are known to possess a mesoglœal sphincter, as, for instance *A. pallida* (Ag.), *A.* sp. (from the Bermudas, McM.) and *A. lucida* (Duch. & Mich.) Duerden. In all these, it is true, the muscle is exceeding weak, but it nevertheless is present, and its absence in certain species is merely the fulfillment of the reduction of it which is characteristic of the genus. A separation of the forms with no mesoglœal sphincter would be an act of violence, and, if this be avoided, the genus *Aiptasia* is properly referable to the Metridiinæ.

In the second place, it does not seem to me that a recognition of the Phelliinæ and Chondractiniinæ as distinct subfamilies is necessary. Both lack cinclides, have a coriaceous column wall

provided with an epidermis, a distinct mesoglœal sphincter and only 6 pairs of perfect mesenteries. Haddon makes the distinction rest upon the occurrence of gonads in the mesenteries of the first cycle which he has found in certain Phellias. It does not seem to me that this peculiarity deserves the importance that Haddon has assigned to it, and I may again refer to the genus *Aiptasia* as providing ammunition for use against my friend's proposition. In *A. pallida* and in *A.* sp. (Bermudas, McM.) gonads occur in the mesenteries of the first cycle, and yet I imagine that no one would therefore suggest the assignment of these species to a different subfamily than that which shelters *A. annulata*, etc. We may, apparently, find occasionally an infringement of the right of sterility usually enjoyed by the first-cycle mesenteries, but it does not seem to me that we should at present legitimize the infringement by granting it the rank of a subfamily characteristic.

In the present collection I have found no representatives of either the Sagartiinæ or Phelliinæ, but a representative of the Metridiinæ occurred.

Subfamily METRIDIINÆ, Carlgren.

Sagartiidæ in which the column wall is perforated by cinclides and in which only the mesenteries of the first cycle are perfect.

1. Metridium dianthus (Ellis) Oken.

Synonyms.—Actinia dianthus, Ellis, 1767.
Actinia plumosa, Müller, 1776.
Metridium dianthus, Oken, 1815.
Actinoloba dianthus, Blainville, 1830.
Actinia marginata, Lesueur, 1817.
Metridium marginatum, Milne-Edwards, 1857.
Metridium fimbriatum, Verrill, 1865.
? Actinia priapus, Tilesius, 1809.

(For a more complete synonymy see Andres, '83.)

As may be seen from the above synonymy, I have united into a single species three forms which have been usually regarded as distinct, though several authors have recognized the possibility of their identity. I wish it to be understood, however,

that in employing the specific term *dianthus*, I do not desire to imply any prejudice to the claims to priority of two other terms, namely the *felinum* of Linnæus and the *pentapetala* of Pennant; I have not access at present to the works in which these terms were first used, and cannot, therefore, decide as to their validity.

Habitat.—I find in the present collection several representatives of this species, the majority of which were collected in shallow water principally from the piles of wharves or from stones, two specimens only coming from deeper water, one from 9.5 meters, where it was adherent to a deserted clam shell, and the other from 13.7 meters.

External Form.—Allowing for differences plainly due to size and degree of contraction, the external form is essentially the same in all the specimens. The base is adherent and the column is essentially cylindrical and smooth, except for, in some cases, fine longitudinal or transverse ridges, evidently due to contraction. A short distance below the margin there is a well-marked circular fold or collar, above which the wall is considerably thinner than it is below, and scattered over the surface below the collar, cinclides may be observed.

The margin is distinctly lobed and is tentaculate, the tentacles being very numerous and closely crowded in many cycles. They are rather short, and acuminate and entacmæous; I do not find, however, that the relative length and thickness of the tentacles is the same in all the specimens, differences of contraction causing them in some cases to be rather conical in shape, while in others they are much more slender and almost filiform. The disk is smooth and slightly concave, the mouth being somewhat prominent. The lips appear to be tuberculate, this appearance being due to the continuation upon them of the longitudinal ridges which occur upon the stomatodæum. In all the specimens in which the mouth is visible two gonidial grooves can be distinguished, except in one specimen in which there seemed to be only one.

Color.—Dr. Calkins' notes of the various specimens show that they can be arranged in three groups according to the prevailing color. Thus there is a group (I) in which the column

is of a *brown* color, the tentacles being of the same color, while the lips are usually yellowish or orange. Dr. Calkins' description of one of the members of this group is as follows: "Light brown with long feathery tentacles of still lighter color. The extreme tips of the tentacles are white. The mouth parts are almost an olive green" and the disk is "transparent from mouth to margin."

In a second group (II), the column is of an orange or salmon color. Four representatives of this group occur in the collection: one of these Dr. Calkins describes as being of a "bright orange" color, and the other three as being "yellowish pink."

The third group (III) has but two representatives in the collection and these are described by Dr. Calkins as being "pure white."

Size.—The specimens belonging to the brown variety are on the whole smaller than the others. Some of them are, however, considerably contracted, measuring, in this condition, 1.3–1.5 cm. in height, the base being broadly expanded and measuring 1.8–3.5 in diameter, while at the upper part of the column the diameter is only 1.3–1.2 cm. One specimen, which was well expanded measured 3 cm. in height and had a diameter at about half way up the column of about 1.5 cm., while the base measured about 2 cm. Another specimen, also well expanded is about 4 cm. in height and about half way up the column has a diameter of 2.3 cm.

The specimens belonging to the orange variety have a greater average size. Three specimens measured 2.3 cm., 1.5 cm., and 3.5 cm. in height, with a column diameter of 2.3 cm., 1.3 cm., and 2.5 cm. respectively. Another specimen, taken at a depth of 13.7 meters, was much larger, measuring in its present condition, 12.5 cm. in height, the base having a diameter of 4.5 cm. and the column about its middle measuring 3.7 cm. in diameter. These figures do not, however, represent the original size of the specimen, since Dr. Calkins states that soon after it was placed in formalin its dimensions were "seven inches from base to mouth, five inches across the crown and three inches in diameter."

The two white specimens are of about the same size and measure 8 cm. in height and about 4 cm. in diameter.

As stated above, considerable variation occurs in the length of the tentacles. Thus in a brown individual measuring 4 cm. in height the inner tentacles measured 3.5 mm. in length, while in another individual of the same variety, measuring only 1.3 cm. in height, the inner tentacles were 5 mm. long. In the large orange specimen the inner tentacles measured about 4 mm.

Structure.—Considerable differences in the structural details are found in the various individuals, but these seem to be correlated, in part at least, with differences of age, that is to say of size. A comparison of the structure of the smallest individual with that of the largest would almost lead one to regard the two as distinct species; intermediate conditions, however, occur and it seems clear that the differences are growth differences associated with some tendency to variability.

The mesoglœa of the column wall has a fibrillar structure, or is even distinctly fibrous, especially in the region of the sphincter. Above the level of the collar the wall is much thinner than below, the difference being due to a difference in the thickness of the mesoglœa. The circular musculature of the column is well developed and in the smaller specimens, its mesoglœal processes are clearly marked off and show a tendency to branch slightly. In the larger forms, however, they are sometimes stout, with rounded extremities and may contain muscle cavities imbedded in their substance.

The sphincter is always well developed and is imbedded in the mesoglœa in the collar region. In different individuals, however, it presents decided differences in its minuter structure and I give on Pl. I three figures (Figs. 1, 2 and 3) showing some of the variations observed in the present collection. In Fig. 1, which is from an individual measuring 1.5 cm. in height, the muscle cavities are more or less circular and are scattered irregularly in the mesoglœa, being separated by a narrow band from its endodermal surface. In Fig. 2, which represents only a portion of the sphincter of an individual of the white variety measuring 8 cm. in height, the muscle cavities are much more

numerous and extend quite up to the endodermal surface of the mesoglœa, even the processes found on that surface containing numerous cavities. In Fig. 3, finally another arrangement is shown. The preparation from which the drawing was made was from a brown specimen which measured 3 cm. in height, and the peculiarity which it presents lies in the band of mesoglœa destitute of cavities which traverses the muscle longitudinally, dividing it into an outer and an inner portion, the latter being separated from the endodermal surface by a distinct interval as in Fig. 1. This last condition recalls the arrangement figured by Carlgren (**'93**) for the European *M. dianthus* and may be termed the "layered" condition.

The occurrence of a band of mesoglœa, destitute of muscle cavities, between the inner surface of the sphincters and the endoderm is probably to be regarded as leading to a layered condition of the muscle. If, in a specimen similar to that from which Fig. 1 was taken, the inclusion of muscle fibers within the mesoglœa were to occur again with the continued growth of the individual, an arrangement would be found similar to that seen in Fig. 3, and an alternation of periods of growth during which inclusion went on with periods in which it ceased, would result in the arrangement figured by Carlgren. It may be presumed that in the larger specimens of *M. dianthus* a layered arrangement of the sphincter will be the most frequent, but cases like that represented in Fig. 2 show that it is not an invariable arrangement for the species.

I have examined the structure of the cinclides in one specimen of the collection and find that it agrees with what Carlgren has described for the European individuals, the canals being lined by endodermal cells, so that the cinclides may be regarded as endodermal evaginations. The same is true with regard to a specimen from our eastern coast (the *M. marginatum* Auct.), and this mode of formation may probably be regarded as typical for *Metridium dianthus*, though further observations are necessary to determine whether it can be regarded as characteristic of the entire subfamily.

The longitudinal musculature of the tentacles, and the radial

musculature of the disk is ectodermal and but moderately developed. The stomatodæum is provided with well-marked longitudinal ridges, and in all the six specimens which were examined with regard to this point *two* siphonoglyphes were present.

In all the specimens examined, with a single exception, there were six pairs of perfect mesenteries, two of these being directives. In the majority of the specimens there were altogether five cycles of mesenteries, that is to say ninety-six pairs, but in some there were only four cycles and occasionally the fifth cycle was only imperfectly developed. In the exceptional specimen referred to above, there were only four pairs of perfect mesenteries. Two of these were directives, and between these two pairs on one side there were two pairs of perfect mesenteries, but none on the other. In other words, the irregularity affected only one-half of the specimen. In the normal half there were five cycles of mesenteries represented, the mesenteries of the fifth cycle, as is usual, lacking mesenterial filament. In the irregular half the various cycles could not be determined accurately, but judging from the relative breadths of the mesenteries the arrangement was D-iv-iii-iv-ii-iv-iii-iv-iii-iv-D, the mesenteries of the fifth cycle being omitted in this count.

The longitudinal muscles of the mesenteries were fairly well developed, forming a moderate thickening upon the inner portion of the primary mesenteries as represented in Fig. 4. Occasionally the pennon was somewhat narrower and more prominent, this condition being apparently normal for the directive mesenteries, the pennon in these having the form represented in Fig. 5. Parieto-basilar muscles are hardly at all developed (Fig. 4), and the basilar muscles have the form described by Carlgren, though not usually as large as those he has figured.

In only two specimens of those examined were reproductive organs present; in these they were borne upon the mesenteries of the second, third and fourth cycles. Acontia occurred and both the inner and outer stomata were found in the perfect mesenteries.

The specimens here described are undoubtedly identical with those described by Verrill ('**65** and '**69**) as *Metridium fimbria-*

tum. Verrill founded this species (**'65**) on a specimen from San Francisco, but later (**'69**) gave a more complete description based on additional specimens from Puget Sound. In both papers he states his belief that the species is closely allied to the *M. marginatum* of the Eastern Coast of America, differing from it, however, "chiefly in having longer and more slender tentacles, with the parapet further from the margin of the disk." He further suggests that *M. marginatum*, *M. fimbriatum* and *M. dianthus* "will eventually be found to belong to one very variable and widely diffused species.

Andres (**'83**) considers *M. fimbriatum* a synonym for *M. marginatum*, accepting Verrill's suggestion to this extent, and though retaining *marginatum* distinct for *dianthus*, states his belief that it may be identical with that form.

We have here two questions of synonomy to consider: (1) Is *M. fimbriatum* identical with *M. marginatum?* (2) Is either of these species identical with the European *M. dianthus?* To the first of these questions I would answer in the affirmative. I have carefully compared specimens of *M. marginatum* from the coast of Massachusetts (Woods Holl) with the Puget Sound specimens, and, allowing for the variability which seems to obtain even in specimens from the same locality, I see no reason for regarding the two as distinct. It may be well however to compare in some detail the specimens from the two sides of the Continent, that my conclusions in the matter may not be merely *ex cathedrâ* statements.

1. As to the coloration. It has been stated above that three principal color varieties occur in the Puget Sound specimens. The same three varieties are readily distinguishable in the Woods Holl individuals, and, in connection with this, two points of some interest may be incidentally referred to. So far as I have seen in the examination of several hundred specimens of the east coast form, the smaller individuals are always brown, the individuals of a salmon or white color being invariably large and one is tempted to suppose that the salmon and white varieties are not distinct from the brown variety from the beginning, but that the brown color is characteristic of all younger individ-

uals and is, in some cases, after the individuals have obtained a considerable size, replaced by salmon color or by white. In support of this idea it may be stated that individuals are frequently found whose color is chiefly salmon or white, but whose column is splashed with irregular bands, spots or dots of brown. This fact seems to be true also of the Puget Sound forms according to the description given by Verrill ('**69**). Of course all individuals do not necessarily undergo a change from the brown color with advancing age, since brown forms may frequently be found quite as large as the individuals of the other colors.

The second point to which I wish to call attention receives a simple explanation from the conclusion just stated. Salmon-colored individuals blotched with brown are not uncommon and white individuals similarly marked are also found, but, never as far as I have seen, do individuals of a salmon color blotched with white, or *vice versâ*, occur. In other words the salmon-colored and white varieties never merge into one another while both merge into the brown variety.

2. As to dimensions the specimens which I have collected at Woods Holl agree in size fairly well with those of the present collection, except that I have never found any East Coast specimen as large as the largest Puget Sound specimen. Verrill, however, states ('**64**) that the more northern forms, especially those from the Bay of Fundy, are larger than those from more southerly localities.

3. As to external form I have not been able to distinguish any constant differences in the external form of the individuals from the two localities. The differences which Verrill considered to exist in the slenderness of the tentacles and the distance of the collar from the margin cannot be regarded as of much importance since they are apt to be due to contraction ; I find indeed as much difference in both these respects between different specimens from Puget Sound or Woods Holl as between specimens from the two localities.

As to internal structure. Making due allowance for the variability in the details of the internal structure shown to exist in the Puget Sound specimens, and for the similar variability occur-

ring in the East Coast specimens, I can see no reason for considering the two distinct. In nearly all essential peculiarities there is practical similarity, the striking differences being in the apparent absence of variation in the number of siphonoglyphes and directives in the Puget Sound specimens. This difference will, however, be discussed later.

One other point may be mentioned. *M. marginatum* has been described from the coast of New Jersey to as far north as Labrador, *M. fimbriatum* from San Francisco and Puget Sound and Dr. Calkins informs me that it also occurs at Sitka. There is no record however of its occurrence in more northerly regions, the report from the American Station of the International Polar Expedition at Point Barrow (Murdoch '**85**) making no mention of any species which can be considered a Metridium. If, however, the East and West Coast species are identical it is probable that further observation will reveal their presence in the Arctic regions.

The specific identity of the East and West Coast forms being regarded as established, the question as to their identity with the European *M. dianthus* may now be considered. As pointed out above, suggestions as to their identity have been made, and, indeed, the American form has been actually identified with *dianthus* by some authors. Thus Couthouy ('**38**) speaks of the occurrence in the Charles River at Boston of *Actinia plumosa* Müller; and Dawson ('**58**) describes specimens from the Gaspé basin "which appear identical with the *A. dianthus* of the British Coast."

Certainly the two forms resemble one another closely both in external form and in coloration, three of the color varieties of *dianthus* recognized by Gosse ('**60**) being identical with those recognized for *M. marginatum*, while the fourth, the yellow, also occurs in the American species, but has been considered above as belonging to the salmon-colored variety. Of the internal structure of *dianthus* several more or less complete accounts exist, the most recent and most thorough being that of Carlgren ('**93**), and on comparing this point by point with what occurs in the American forms, the similarity is so great

that there can be no doubt, I think, as to the identity of the two forms.[1]

I have not in the above discussion considered the variability in the number of the siphonoglyphes and directives, which is so pronounced in the European and American East Coast forms, and which might be regarded as of sufficient importance to be regarded as a specific characteristic. Sufficient data are not available to determine definitely whether this variability also occurs in the American West Coast forms, but in the six specimens I examined it was not observed. But even granting that no variability in this respect occurs in the *fimbriatum* forms, it does not seem that this would be sufficient for considering these specifically distinct from the *marginatum* and *dianthus* forms. No one has suggested that the *dianthus* forms with the siphonoglyphe and one pair of directives should be separated from those with two siphonoglyphes and two pairs of directives, and it would be even less reasonable, it seems to me, to separate *fimbriatum* forms from *marginatum* or *dianthus* forms with two siphonoglyphes and two pairs of directives, other structural characteristics being so similar.

There are not at present sufficient data at hand for determining accurately the relative frequency of the monoglyphic condition in the European and *fimbriatum* forms. To judge, however, from the statements of Thorell ('58), Gosse ('60), and Carlgren ('93), among others, the monoglyphic condition is by far the most frequent in the European specimens; the thorough observations of Parker ('97) show that it occurs in somewhat over one-half of the total number of *marginatum* forms which he examined; while, as stated above, it would seem to be much less frequent in the *fimbriatum* forms.

At the close of the list of synonyms of the species I have

[1] To judge from certain statements made by Gosse ('60) I should imagine that the relations of the different color varieties described above for *M. marginatum* do not hold for *M. dianthus*. What the physiological causes may be which produce the different varieties is at present unknown, but a fact quoted by Gosse is of interest in this connection. It is to the effect that on a water-logged board brought in by a trawler there were between four and five hundred specimens of *M. dianthus*, and all the individuals "*on one side the board were white, all on the other orange.*"

added *Actinia priapus* of Tilesius. The description which Tilesius gives of this Kamtchatkian form, though given at some length and accompanied with numerous figures, leaves one in considerable doubt as to its actual affinites. The figures of the entire animal given in his Pl. XIV, certainly resemble very greatly large specimens of *M. dianthus*, especially those contained in the present collection, and I should have little hesitation in identifying with that species were it not for Fig. 1, of Pl. XV, which suggests a Thalassianthan character for the tentacles. Andres has accepted this figure as representing the true structure of the tentacles and has assigned the form to a new genus Dendractinia, placing it however among the *Actiniae incertae sedis.* It seems to me quite probable however that the structure of the disc shown in Pl. XV, Fig. 1, is not natural but has been made by dissection, the figure being of a dissected specimen. In the text (p. 407) Tilesius says that the disk "in quinque vel sex ramos, ramulos et surculos papilliferos villiferosve divisus et subdivisus est, ita, ut peripheria disci a numerosissimis tentaculorum fasciculis formetur." This might be taken as confirming the accuracy of Fig. 1, but earlier in the paper (p. 396) be divides Actiniæ into two groups, of which the first contains "actinias disco diviso, scilicet in ramos ramulos et surculos tentacula efformantes" and includes *Actinia plumosa*, Müller, *Priapus polypus* Forskål, *Actinia effocta* Baster and *Actinia priapus.* The same description then which he applies to the tentacles of *A. priapus* serves also for *A. plumosa*, and this, taken in connection with the figures in Pl. XIV, seems to me to render exceedingly probable the identity of *Actinia priapus* with *Metridium dianthus.* It may also be mentioned that from what we now know of the distribution of *M. dianthus* there is reaaon to expect its occurrence on Kamtchatkian shores, while, on the hand, the occurrence of a Thalassianthid is not to be expected, since, so far as at present known, such forms are essentially tropical in their distribution.

Finally I may add, that if the identification of *A. priapus* be correct, it is possible that Brandt's *A. farcimen* ('**35**) may also be a synonym.

Family CRIBRINIDÆ.

Synonyms.—Bunodidæ. Gosse, 1858.
Tealidæ. R. Hertwig, 1882.
Bunodactidæ. Verrill, 1890.

Actiniinæ with adherent base, with a strong circumscribed endodermal sphincter; usually with the column more or less verrucose and frequently with acrorhagi at the margin, these, however, never being ramose or frondose. Perfect mesenteries usually numerous and gonophoric. No cinclides or acontia.

I have ventured to employ a new term for the family to which Gosse originally applied the name Bunodidæ. The change I have regarded as necessary on the ground that the family name should be a derivative from the name of the typical genus; my reasons for adopting Cribrina as the name for the typical genus are based upon a strict interpretation of the rules of priority and are as follows:

The family Bunodidæ was instituted by Gosse (**'58**) with the genus Bunodes (established in 1855) as its type, though previously Milne-Edwards had separated all actinians with verrucose column wall to form his group of actinines verruqueuses. Gosse took as the type of his new genus *B. gemmacea*, a form which had long been known and has been referred by Ehrenberg in 1834, to the subgenus Cribrina. An interesting question of priority here arises. The first species mentioned by Ehrenberg under the genus Cribrina, is this very one, and following the rule, it would be taken as the type of the genus. Haddon, however, has adduced reasons (**'89**) for believing that Ehrenberg regarded the fifth species which he included under Cribrina, namely, the *Priapus polypus* of Forskål, as the type, and for this reason retains Gosse's genus. The genus Bunodes certainly cannot be retained, since, as Verrill has pointed out (**'99**), the term had already been applied in 1854 to a genus of Eurypteroidea, and it seems better under the circumstances to consistently apply the rule and disregard Ehrenberg's possible or one might even say probable intention rather than introduce an entirely new term, such as Bunodactis, proposed by Verrill

(**'99**). The genus Bunodella established by Verrill (**'99**, p. 43) has already been withdrawn by him (**'99**, p. 146) and need not be considered here, and the genus Evactis, also established by Verrill, is discussed later, and I need merely state here that after an examination of the type species, *E. artemisia*, Pickering, I see no reason for regarding it as distinct from Cribrina.

In 1834 Ehrenberg established a subgenus Urticina with the *A. crassicornis* of Müller as the type and later Gosse (**'58**) established for the same form the genus Tealia. The priority of Ehrenberg's term is generally admitted and consequently the use of Hertwig's name Tealiidæ for the family is inadmissible since Tealia is a nomen delendum.

I shall have occasion later to discuss another group of generic terms namely Anthopleura Duch. & Mich., Aulactinia Verrill, Ægeon Gosse and Bunodosoma Verrill, and may state here simply my belief that they cannot be separated but must all be included under the title Anthopleura.

The genus Phymactis M. Edw. (**'57**) has usually been regarded as a Cribrinid (Bunodid), Haddon, I believe, being the first to suggest that it might possibly be more correctly referred to the family Aliciidæ. Carlgren in a recent paper (**'99**) has published the result of his studies of *P. clematis* (Drayton), of which he finds Milne-Edwards' type species *P. florida* (Drayton) to be a synonym, and shows that Haddon was correct in his suggestion. I may add that I can confirm Carlgren's conclusions both as to the reference of the genus to the Aliciidæ and as to the synonymy of the two species mentioned, but may point out that one species, *P. cavernata*, which in the past has generally been referred to the genus Phymactis, must be removed from this genus and referred to Anthopleura. Verrill has practically already (**'99**) made the transfer, since he has included the species in his genus Bunodosoma.

With regard to the remaining genera which have been referred to the family little may be said, as for the most part too little is known of them to allow of certainty as to their true positions. I have already (**'97**) suggested the reference of Gyractis Boveri, to the Bunodidæ a suggestion which has been accepted by

Haddon. Carlgren's Isotealia ('99) must be allowed to stand for the present on account of the imperfect information in our possession concerning Hertwig's Leiotealia ('82) with which it is possibly identical, and Haddon's Ixalactis ('98) and Klunzinger's Thelactis ('77) will also stand as somewhat aberrant members of the family though it must be confessed that at present we are entirely in the dark as to the true systematic position of Thelactis as we are also to that of Physactis Verrill ('69), the last named genus being quite probably really an Aliciid, somewhat similar to Haddon's *A. rhadina* ('98). The genus Epiactis (Verrill '69) is considered further on.

Finally there remain to be considered Pseudophellia Verrill ('99), Tealiopsis Danielssen ('90) and Epigonactis Verrill ('99). Danielssen refers his *Tealiopsis polaris* to R. Hertwig's Tealidæ without however giving any definite evidence of its possessing the qualifications necessary for admission to that family; it may possess a circumscribed endodermal sphincter but neither in the text nor figures is there any indication of the existence of such a structure. If it does occur, then there seems to me a probability of Verrill's Pseudophellia being identical with Tealiopsis; it is impossible at present to speak with certainty on this point, however. Verrill's Epigonactis was established quite recently ('99) for two species which closely resemble each other and are not a little suggestive of *Urticina crassicornis* from which they are distinguished however by possessing on the surface of the column depressions which serve as "brood-pouches." With regard to the systematic value of this peculiarity I am exceedingly sceptical and believe that judgment on the admissibility of the genus must be suspended until a more detailed description accompanied with figures showing the structural details has appeared.

My views as to the relationships of the various genera mentioned above may be briefly expressed thus:

Cribrina, Ehr.—Synonyms, Bunodes Gosse, Evactis Verrill, Bunodactis Verrill, Bunodella Verrill.

Urticina, Ehr.—Synonyms, Tealia Gosse, possibly Epigonactis Verrill.

Anthopleura, Duch. & Mich.—Synonyms, Aulactinia Verrill, Ægeon Gosse, Bunodosoma Verrill.

Leiotealia, Hertwig.
Isotealia, Carlgren—possibly a synonym of Leiotealia.
Epiactis, Verrill.
Gyractis, Boveri—possibly a synonym of Cribrina.
Ixalactis, Haddon.
Pseudophellia, Verrill—possibly a synonym of Tealiopsis.
? Tealiopsis, Danielssen.
? Thelactis, Klunzinger.
? Physactis, Verrill.

Representatives of the first three of these genera occur in the collection.

Genus Cribrina Ehr.

Cribrinidæ without true acrorhagi; usually with numerous perfect mesenteries which are in some cases arranged on other than a hexamerous plan; sphincter strong; ectodermal musculature of the disk and tentacles not imbedded in the mesoglœa; column wall destitute of an epidermal covering and provided with verrucæ arranged more or less distinctly in vertical rows; tentacles simple.

Rather too much attention has been devoted in the past to the arrangement of the verrucæ, in members of the Cribrinidæ, whether they were arranged distinctly in vertical rows or not and whether these rows extended all the way down the column or only part of the way down. I plead guilty to such a misunderstanding of the value of the verrucæ in an earlier paper ('89) in which, basing my identification on this feature I described as an Aulactinia (*A. stelloides*) a form which is really a Cribrina and as a Bunodes (*B. tæniatus*) a form which is really an Anthopleura (*A. granulifera*).

It seems now that the presence of verrucæ, without regard to their arrangement, is sufficient for the genus, distinguishing it at once from Leiotealia, Epiactis and Isotealia. The absence of true acrorhagi, characterized by a marked development of nematocysts, distinguish it from Anthopleura, while the ectodermal situation of the longitudinal muscles of the tentacles and of the radial muscles of the disc may serve as a distinction from Urticina.

From Ixalactis and Pseudophellia it is readily separated by the simplicity of the tentacles and by the absence of an epidermal covering to the column wall.

2. *Cribrina elegantissima* (Brandt)

Synonyms.—Actinia (Taractostephanus) elegantissima, Brandt.
? Urticina crassicornis, Verrill.

The identification of the species here described with Brandt's *A. elegantissima* is necessarily somewhat uncertain, since the original description is not as complete as could be wished. So far as the description goes, however, the agreement is sufficiently close to warrant the identification.

Habitat.—" A very common form on the rocks and piles " in Puget Sound. (Calkins.)

External form.—The base is circular and adherent. The column is almost cylindrical (**Figs. 7** and **8**) and in its upper part is provided with vertical rows of verrucæ, which become obsolete towards the base. Some of the rows extend much farther down the column than others, and according to their length, about four sets can be distinguished, of which the third and fourth sets are much shorter than the other two. The lower part of the column is ridged transversely probably as the result of contraction. A well-defined margin is present, and a distinct interval exists between it and the bases of the outermost tentacles.

These are short, rather blunt at the apex and all finely ridged longitudinally. They appear to be arranged in about five cycles, though their total number does not agree with what would be expected from such an arrangement ; as will be seen later there are irregularities in the arrangement of the mesenteries which probably explain the irregularities of the tentacles. The disk is marked by fine radiating furrows and is slightly concave, the peristome being prominent. In two of the specimens the stomatodæum is somewhat evaginated and it can be seen that its walls are longitudinally ridged. Two siphonoglyphes seem to be present as a rule, though sometimes irregular in position, and in one individual there were three, and in another only one.

Color.—The specimens when I received them were in formalin and showed a distinct green coloration in the upper part of the column, while the lower part was a dingy white. On transferring them to alcohol the green coloration gradually disappeared, the pigment to which it was due being evidently soluble in that medium. In life the coloration, according to Dr. Calkins' description, was quite brilliant. He says, "The ground color is bright green while rows of bright red vary it. Each tentacle is colored in the middle by a ring of brown and the tip is of the same color. They are very gorgeous" (**Fig. 8**).

Brandt's description of the coloration of his *A. elegantissima* is as follows: "Red, green, blue or fuscous, or even green spotted with purple. Disc olivaceous, striated with white. Tentacles white, purple at the tips and marked at the middle by a purple band." Comparing this with Dr. Calkins' description a decided similarity is noticeable, Brandt's account, however, indicating considerable variation in the color of the column. The markings of the tentacles Calkins describes as brown, while Brandt states that they are purple, a discrepancy perhaps due to variation, or perhaps to the uncertain way in which the term purple is frequently used. In both descriptions the arrangement of the markings is identical.

Size.—The three specimens sent me were all apparently small, measuring 3, 1.8 and 2.5 cm. in height, and 3, 3, and 1.5 cm. in breadth, respectively. Dr. Calkins in his notes says that some individuals "are of large size, five or six inches long and three or four in diameter, and Brandt's statement regarding the size is "Corpus magnum." The inner tentacles have a length of about 0.4–0.5 cm., while the outer ones seem to be slightly longer.

Structure.—The verrucæ are hollow outpouchings of the column wall (**Fig. 9**). The circular musculature of the column is well developed in the intervals between the verrucæ and is supported upon branched mesoglœal processes, which are frequently grouped together in bunches arising from a common base. The walls of the verrucal outpouchings are, however, almost destitute of musculature, except at the very

summit of the pouch. Here a small number of muscle processes may be seen projecting from the inner surface of the mesoglœa, which is here slightly thickened. The ectoderm over the summits of the verrucæ is similar to that described for the verrucæ of *Cereus pedunculatus* by von Heider ('**77**) and for those of *Phymanthus crucifer* by myself ('**89**), the layer of cells at the base of the epithelium in the latter form being also present here. Indeed, the only difference between the structure of the verrucæ of the present species and those of Phymanthus is the existence of a special musculature on the endodermal surface of the summits of the papillæ in the former.

The sphincter, which occurs below the fosse intervening between the margin and the bases of the outermost tentacles, is of the circumscribed pedunculate bipinnate variety[1] (**Fig. 10**), and is strong. The ectodermal musculature of the disc is well developed, the processes of mesoglœa which support it anastomosing somewhat to form a reticulum, a condition intermediate between the typical ectodermal and the mesoglœal arrangements being thus produced (**Fig. 11**). Transverse sections of the tentacles show that their ectodermal musculature is also well developed, but no anastomoses of the mesoglœal processes occur (**Fig. 12**).

The walls of the stomatodæum are thrown into well-marked longitudinal ridges and are richly supplied with glands, except

[1] It seems advisable that certain terms should be agreed upon for the description of the principal varieties of endodermal and mesoglœal sphincters. So far as the endodermal are concerned, the terms "diffuse" and "circumscribed," already in general use, serve to divide them into two groups; but a further subdivision of the circumscribed forms would be useful. I would suggest as a first subdivision that those which arise by a number of main branches from the column mesoglœa, as in *Myonanthus ambiguus* and *Oulactis californica* for example, be grouped as "sessile," while those which have a distinct peduncle be termed "pedunculate." The latter group may again be divided, according as the lamellæ radiate from a central mass or are inserted into an axial lamella, into "palmate" and "pinnate" varieties. Such a classification may be represented in tabular form, thus :

Endodermal sphincter	diffuse.		
	circumscribed	sessile.	
		pedunculate	palmate.
			pinnate.

Such a classification is of course merely tentative and presumably imperfect, but it may serve to some extent to obviate the long description now necessary.

in the regions of the siphonoglyphes. That irregularities occur the arrangement of the latter structures has already been noted. In one of the three specimens which I sectioned I found three siphonoglyphes, while in the second individual though only two were present they were not opposite one another, thirty-seven pairs of mesenteries intervening between the two on one side while on the other side there were fifty-five pairs. In the third specimen but a single siphonoglyphe occurred.

In connection with the siphonoglyphe a peculiarity of structure exists. The endoderm over the general surface of the stomatodæum is comparatively low and inconspicuous, but in the region of the siphonoglyphes it suddenly becomes very high and retains this condition over the entire surface of the grooves (**Fig. 12**). I speak of the endoderm being thickened, but the appearance is rather as if the endodermal surface of the mesoglœa were drawn out into exceedingly fine fibrillæ which anastomose with one another to form a reticulum with elongated meshes, the endodermal cells being arranged on the terminal part of the fibrillæ. The appearance presented is very similar to that which I have described as occurring in the mesenteries of *Cerianthus americanus* ('**90**).

The individual with three siphonoglyphes had three pairs of directives, while the one with two siphonoglyphes had correspondingly two pairs unequally spaced, and the third specimen with one siphonoglyphe had but a single pair. As might be expected from the arrangement of the directives considerable irregularity occurred in the mesenteries. In the upper part of the column each alternate pair seemed to be perfect as a rule, but lower down seven imperfect pairs intervened in certain sectors between successive perfect ones. It may be supposed from this that there were typically four cycles of mesenteries, three of which were perfect and one imperfect. The typical arrangement occurred however only in a few sectors ; examples of a fifth incomplete cycle occurred here and there and in addition both imperfect and perfect pairs were not infrequently intercalated so that it was impossible to determine even whether the arrangement was hexamerous or not, although it may be supposed that in one specimen at

least it was decamerous. To illustrate the irregularity which exists, **Fig. 1**, representing the arrangement of the mesenteries in the specimen with two siphonoglyphes a little below the middle of the stomatodæum, is appended.

Attention may be called to one interesting irregularity in this specimen, and that is the development of two pairs of mesenteries in the endocœl of one of the perfect pairs.

The longitudinal musculature of the perfect mesenteries is fairly well developed (**Fig. 14**) and there is a well-marked parieto-

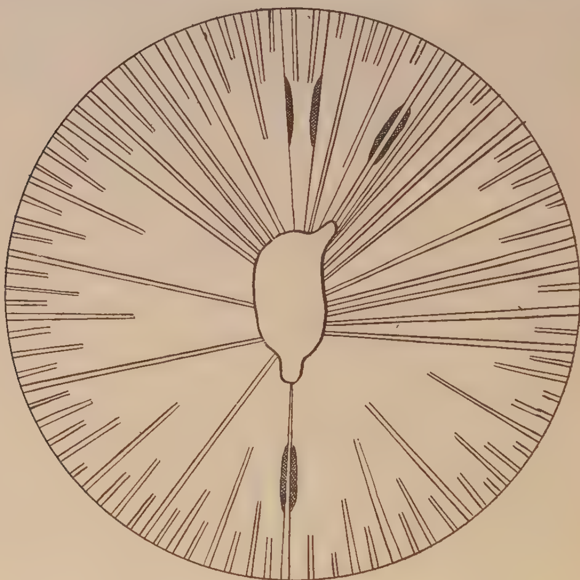

FIG. I.

basilar forming a fold upon the peripheral portion of each mesentery. Both inner and outer mesenterial stomata are present. Reproductive organs may apparently be developed on any of the mesenteries, with the exception of the directives and of the incomplete cycle, but in the two specimens examined minutely with this point in view they are not distributed with perfect regularity, some mesenteries of every cycle lacking them.

There is no doubt but that in many respects of structure this form approaches closely to *Urticina crassicornis*, the differences

in the arrangement of the ectodermal musculature of the disk and tentacles and in the form of the sphincter being possibly explicable on the assumption that the specimens examined by me were all young. I have not had the opportunity of comparing any of the large specimens of this species with fully grown urticinas, but it would seem that the irregularities in the siphonoglyphes which occurred in all of the three specimens examined indicate the distinctness of the species, since such irregularities have not been found to occur in Urticina.

3. *Cribrina artemisia* (Pickering)

Synonyms.—Actinia artemisia, Pickering in Dana.
Cereus artemisia, Milne-Edwards.
Evactis artemisia, Verrill.

Habitat.—The individuals of this species were found at Discovery Bay, the same locality from which they were originally described by Dana (**'46**). They live buried in the sand, the disk being flush with the surface in expansion, and are attached below to valves of shells or more rarely to stones.

External Forms.—The base is adherent and the column in contraction is club-shaped (**Fig. 25**). A short distance above the limbus the column suddenly contracts and then gradually enlarges again until above it may equal or exceed the base in diameter. In all three specimens which I had for examination the tentacles and disk were completely hidden and the upper extremity of the column presented an almost flat surface, slightly depressed towards the center. The appearance presented by these specimens little resembles accordingly the figure given by Dana, but it must be remembered that this figure is of an expanded individual. Dana describes the column as being enlarged at its middle and contracted more or less above and below. It is probable that in the preserved specimens the upper contracted portion is completely involuted, and the enlarged extremity corresponds to the middle enlargement of the expanded form.

The column in its lower part is horizontally rugose, evidently as the result of contraction, and is provided with a

number of rather low tubercles arranged in about twelve longitudinal rows, the individual tubercles of each row being separated by considerable intervals. Higher up, where the column begins to enlarge, the rows are more numerous, and at the upper part, the tubercles become decidedly papilliform. They are arranged in about 96 rows and have particles of sand and shell adhering to them, their verrucal nature being thus demonstrated.

By dividing the column longitudinally, it became evident that there were no acrorhagi, the papillæ of the margin being the uppermost verrucæ of the longitudinal rows.

The number of the tentacles could not be determined with certainty. They were simple, rather short and acuminate, and, as Dana has stated, are ectacmæous. The disk and mouth were hidden in all the specimens.

Color.—The coloration as stated in Dr. Calkins' notes differs a little for that described by Dana. It was "greenish-yellow" at the upper portion of the column and "yellowish-white" lower down, while the tentacles are stated to have "scarlet or purplish tips." According to Dana, who quotes a description by Drayton "the general color of the exterior of the body is a yellowish-green. The tubercles have a dark sap-green color; they become obsolete below, yet the green line continues to the base of the animal. The colors of the tentacles are various and shaded like those of the prism; the disk is dull greenish, becoming darker towards the base of the tentacles, and the mouth is flesh-colored."

Size.—In the preserved specimens the base measured 2.5 cm. in diameter. The column a short distance above the limbus, at its narrowest point, measured 1 cm. in diameter, but above it equalled the diameter of the base or even reached a diameter of 2.8 cm. The height of the column was about 6.0 cm.

The inner tentacles were about 0.5 cm. in length, while the outer ones measured 0.65–0.7 cm. For the expanded animal, Dana gives the greatest diameters of the column as about 5.5 cm. (2¼ inches), while the outer tentacles he states to have been 2.5 cm. (1 inch) in length and the inner ones 1.25 cm. (½ inch).

Internal Structure.—The mesoglœa of the column wall is, relatively to the size of the individuals, rather thin and is provided with a well-developed circular musculature, whose general appearance resembles that of *C. elegantissima*. In the upper part of the column, however, it is comparatively poorly developed, and also on the inner walls of the evaginations which produce the verrucæ, being entirely wanting at the apex of these.

The sphincter (**Fig. 18**) is large and is of the pedunculate bipinnate type, the lateral lamellæ of one side being, however, stronger than those of the other so that it is properly described as unequally bipinnate. In one of the three specimens a deep incisure occurred on one side of the sphincter, reaching almost to the median axis and giving the section of the sphincter a reniform outline. This was wanting, however, in the other two in which the sphincters were oval in section.

The tentacles are not ridged and have a well-developed, though simple, ectodermal musculature. Their endoderm, as well as that of the disk and of the upper part of the column wall, is richly laden with granules of black pigment, insoluble in the reagents employed in hardening and sectioning. The ectodermal musculature of the disk (**Fig. 18**) resembles that of the tentacles, being supported on well-developed simple or but slightly branched processes of mesoglœa.

Two siphonoglyphes are present and the walls of the stomatodæum are longitudinally ridged and in addition considerably folded.

The mesenteries are arranged in four cycles and there are in all forty-eight pairs (6, 6, 12, 24). In sections through the upper part of the column all but those of the fourth cycle are seen to be perfect, but below the level of the stomatodæum the various cycles can be distinguished by the relative breadths of the various pairs, those of the first and second cycles being however nearly similar in this respect. The mesenteries of the fourth cycle do not bear mesenterial filaments and there are two pairs of directives, placed symmetrically.

The longitudinal musculature is well developed (**Fig. 19**), covering almost half of the non-gonophoric portion of the

mesenteries and ending somewhat abruptly at either edge. At the outer edge a mesoglœal process, stronger than usual, is developed and from it a number of mesoglœal processes arise. The parieto-basilar muscles form a distinct fold on the lower portions of the mesenteries, and the basilar is fairly well developed, having the appearance shown in **Pl. III, Fig. 20.**

Both the inner and outer mesenterial stomata are present, and all the mesenteries, with the exception of those of the fourth cycle and the directives, bear reproductive organs.

From the examination of this species it has seemed to me impossible to separate it from the genus Cribrina. Verrill ('69) has established for its reception the genus Evactis characterized by possessing pores in the column wall as well as verrucæ and by the tentacles being ectacmæous. I have not been able in sections to discover any distinct pores in the column wall and am inclined to believe that the emission of jets of water "as from a watering pot" which has been observed, was through minute ruptures of the wall, the mesoglœa being comparatively thin especially in the upper part of the column. If this be correct, little importance can be attributed to their power of ejecting water. The tentacles of *C. artemisia* are, indeed, ectacmæous but in every other respect the form has the typical structural characteristies of a Cribrina, and it seems advisable to regard the ectacmæous arrangement of the tentacles as a specific rather than as a generic peculiarity.

Genus Urticina Ehrenberg.

Cribrinidæ without true acrorhagi; with numerous perfect mesenteries frequently arranged decamerously; sphincter strong; ectodermal musculature of the disk and tentacles imbedded in the mesoglœa; column wall destitute of an epidermal covering, and usually provided with verrucæ arranged more or less definitely in vertical series; tentacles simple.

The synonymy of this genus has been recorded by Andres ('83) and more recently by Carlgren ('93). As at present understood it includes but a single species, *A. crassicornis*, a fact

which renders the establishment of a final definition exceedingly uncertain.

The name Urticina was originally applied by Ehrenberg (**'34**) to a subdivision of his subgenus Actinia Isacmæa, and included numerous forms now assigned to other genera. It was not until much later that the genus became at all definitely limited and then it was under the name Tealia, proposed by Gosse in 1858. The essential peculiarity of the genus according to the definition given by Gosse, was that the verrucæ were scattered irregularly over the column wall and were not arranged in vertical series, and this supposed characteristic was generally accepted by succeeding authors. Messrs. G. Y. and A. F. Dixon (**'89**) pointed out that this peculiarity does not really exist, the verrucæ being really in vertical series, though the regularity of the arrangement is not always readily perceivable, and Carlgren (**'93**) has called attention to the same fact. The original distinguishing peculiarity which separated the genus from Cribrina being thus disposed of, both the Dixons and Carlgren found a new distinction in the decamerous arrangement of the mesenteries, the former authors, indeed, going so far as to suggest that this peculiarity was worthy of being raised to the dignity of a family characteristic.

To establish a genus on its decamerism seems to me, in view of what we now know concerning departures from hexamerism in the Hexactiniæ, to place it on an exceedingly insecure foundation. And that this is true in the present case has been recently shown by Verrill (**'99,** p. 216, note) who states that he found "many specimens [of Urticina crassicornis] hexamerous both as to tentacles and mesenteries; many others decamerous; some octamerous; and a few irregular or unequally developed on opposite sides." A careful study of the mesenteries of the individuals contained in the present collection reveals in no case a perfect decamerism, but an irregular arrangement which appears, however, to be based on a decamerism. Consequently we may, I believe, hold the character of decamerism to be insufficient for the characterization of the genus, and if it is to be maintained distinct from Cribrina, we must seek for other peculiarities.

As the definition I have given above suggests, such a distinction may possibly be found in the enclosure of the longitudinal musculature of the tentacles and the radial musculature of the disk in the mesoglœa, an arrangement which seems to be absent in typical Cribrinas. It must be remembered, however, that as in the case of *C. elegantissimus* described above, transitional conditions between what is found in Urticina and in typical Cribrinas occur, and the absolute value of such a characteristic is accordingly open to question. Personally I am somewhat inclined to regard the distinctness of Urticina from Cribrina as not proven, but prefer to await the discovery either of additional species clearly belonging to the former genus or of transitional forms which will clearly bridge over such differences as may appear to exist between the two.

4. *Urticina crassicornis* (Müller) Ehr.

[For the synonymy of this species vide Andres ('**83**) and Carlgren ('**93**).]

Several specimens of this form, which has previously been described for the West Coast by Verrill ('**69**), occur in the collection and show considerable variation in their external characters.

Habitat.—The majority of the specimens were found attached to stones under wharves and accordingly in shallow water. Two, however, were found imbedded in sand to a depth of six inches or a foot, being attached below to stones. This habit does not seem to be a usual one for the species but Dicquemare ('**73**) has described it for individuals obtained by him at Havre, and Teale ('**37**) speaks of individuals being partly buried in sand on the coast of Yorkshire.

External Form.—It does not seem necessary to give a detailed description of this well-known form, but mention should be made of certain peculiarities presented by the various specimens. And first as regards the verrucæ. These in all the specimens were distinctly in vertical series, but their distribution varied somewhat. In some specimens they were large and

somewhat irregular in shape and were distributed over the entire surface of the column, those towards both the margin and the limbus being, however, smaller than those situated in the intervening region. In others again they became obsolete above, occurring on only the lower two-thirds or three-quarters of the column and in one specimen they occurred only on the lower half of the body, those at the limbus in this case being relatively very small, while those above were larger, about 1 mm. in diameter, but were more scattered, that is to say were separated from one another by larger intervals than usual. In the arenicolous specimens again the verrucæ were limited to the upper third of the column, not extending upwards, however, quite as far as the margin, and the lower portion of the body presented no signs of them, except very faint indications immediately above the limbus. A further peculiarity of these forms was that numerous particles of sand and shell were adherent to the verrucose region of the column, a condition not presented by any other specimens in the collections.

I have not access at present to all the literature dealing with this species, but it seems evident that there is considerable variation in the distribution, size and number of the verrucæ in different individuals. As regards their distribution the verrucæ may present the various conditions described above, or may be apparently entirely absent. To a certain extent at least these variations as seen in preserved specimens may be due to the retractibility of the verrucæ, which, to quote the statement of Teale ('37) "admit of retractibility to such a degree as to render the corium perfectly smooth, so that the small opaque spot alone indicates their former situation; they also can be protruded to nearly a line in length, when they bear a close resemblance to rudimentary tentacula. The eminences on one side are often seen in the utmost degree of protrusion, whilst, on the other, they are scarcely perceptible." In some of the present specimens, "the small opaque spots" mentioned by Teale and due to the peculiar structure of the epithelium of the summits of the verrucæ, could be perceived on those portions of the column which appeared to be destitute of verrucæ, but this was not the

case in the arenicolous individuals. The extent of the protrusion of the verrucæ together with the amount of contraction of the column would bring about variations in the proximity of the verrucæ, which are frequently described as being separated from one another, though in the present specimens they are so closely approximated as to be in some cases more or less quadrangular in outline, owing to mutual contact. So too the amount of protrusion will produce variations in their size; in all the specimens of the present collection the verrucæ about the middle of the column are larger than those above and below, but in the different individuals the size of the largest ones vary, being as much as over 1 mm. in diameter in some specimens, while in others they are less than half that size.

I have discussed these varieties of the verrucæ somewhat at length because they serve to illustrate very pointedly the uncertainty of taking external peculiarities alone as a basis for specific distinctions. When I first examined the specimens of the present collection I regarded the arenicolous forms as quite distinct from the others and it was only after I had studied the internal structure of both that I became certain of their identity.

One other point in the external structure I may refer to briefly namely, the arrangement of the tentacles. The decamerism is fairly well pronounced, but never perfect: thus in one specimen is which an accurate count was made there were 133 tentacles only, instead of the 160 which might be expected. The variations of the tentacles however being associated with the arrangement of the mesenteries, need not be discussed in detail and I mention it merely on account of the importance which has been assigned to it by Cunningham ('89).

Color.—All the specimens collected were uniform in color throughout the column, and were either red or orange brown (the "color of an over ripe banana" Calkins). The arenicolous forms were of a bright vermilion color, with paler tentacles, and their appearance when dug from the sand has been so graphically described by Dr. Calkins that I quote his description. "They look very much like a tomato baked in bread crumbs. They have the same wrinkled appearance of the skin, while the ap-

pearance of the bread crumbs is given by the numerous small pieces of shell attached to the upper end." [1] The tentacles in some of the specimens at least were banded with color. Although none of the specimens showed any traces of green in their coloration, yet such varieties have been described from the West Coast. Verrill ('69) has described them, and one of the drawings of Mr. Agassiz is evidently of an individual of this species in which the color of the column is grass green irregularly blotched with deep red, the tentacles being pinkish, with a dark red band a short distance above the base. The drawing shows no indication of warts in the lower portion of the column; whether or not they were present on the upper part cannot be determined since it is hidden by the tentacles.

Size.—All the specimens were of a goodly size, the smallest measuring about 4.5 cm. in height and diameter while the largest was 7.5 cm. in height and 5.5 cm. in diameter. Dr. Calkins describes one of the specimens as having in life a height of 7.5 cm. and a diameter of 5.0 cm. while another he describes as reaching a height of 12.5 cm.

Internal Structure.—I have found some variation in the form of the sphincter in the Puget Sound specimens. Its general appearance in the majority of the individuals examined resembles closely the condition figured by the Hertwigs ('79), that is to say, the mesoglœal lamellæ radiate out for a central mass of mesoglœa, sometimes more or less homogeneous in appearance, sometimes showing more or less clearly its origin by fusion of the basal portions of the lamellæ. In all my preparations, however, the lamellæ are much more numerous and much more delicate than figured by the Hertwigs, a condition also noted by Carlgren ('93) in the specimens examined by him. It may be noticed that at one point in the periphery of the specimen figured by the

[1] Since writing the above lines I have received from Professor Verrill drawings of a specimen taken at Port Townsend in 30 fathoms which is evidently the same as the arenicolous variety of *Urticina crassicornis* described above. The drawing represents the column as being of a bright scarlet color, with very numerous and distinctly marked verrucæ of a yellowish color in its upper part and with long, rather stout tentacles of a yellowish or buff color without bands but with a certain amount of red at the base.

Hertwigs there is a deep incisure, extending almost to the central core of mesoglœa; I found a similar incision, somewhat more extensive indeed, in one specimen I examined, but in others it was entirely wanting. Carlgren (**'93**) states that in the individuals he examined the arrangement of the lamellæ differed from what the Hertwigs describe in being attached at their bases to an axial lamella instead of a solid core; that is, he finds the sphincter is bipinnate instead of palmate as the Hertwigs describe it. In a single specimen of those I examined I found a typically bipinnate sphincter a figure of which is given on **Pl. I.** (**Fig. 6**). It seems accordingly that we may find in individuals of *Tealia crassicornis*, either palmate or pinnate sphincters, the latter probably representing what may be considered a persistence of an embryonic condition from which the palmate is derived by a fusion of the basal portions of the lateral lamellæ.

As to the arrangement of the musculature of the mesenteries and of the tentacles and disk I find nothing to add to the descriptions given by Carlgren.

It is well known that the mesenteries of *U. crassicornis* are arranged more or less perfectly on a decamerous plan. In none of the specimens I have examined, however, is the total number of mesenteries an exact multiple of ten; thus in one specimen there were altogether 81 pairs of mesenteries, in another 91, and in another 104. The variation from the typical number depends on irregularities in the development of the younger series of mesenteries. Thus in the three specimens just referred to the first three cycles were regularly decamerous, their formula being 10, 10, 20, but considerable irregularity occurred in the succeeding cycles. Thus in the specimen with a total of 81 pairs the fourth cycle was completely developed except that in a primary interspace on one side of one of the directive pairs there were only two representatives of it instead of four, the two pairs which were lacking being those nearest the pair of directives. To compensate for this diminution in the total number, in another primary interspace there were two accessory pairs of mesenteries which may be regarded as representatives of a fifth cycle, and in still another interspace there

was a single additional pair of this fifth cycle. In the individual with a total of 91 pairs irregularities occurred in only two of the primary interspaces. The fourth cycle was completely developed so that there were 10, 10, 20, 40 = 80 pairs of regular mesenteries; and in addition 11 pairs representing a fifth cycle. Eight of these were situated in a primary interspace next one of the directive pairs and alternated in a regular manner with

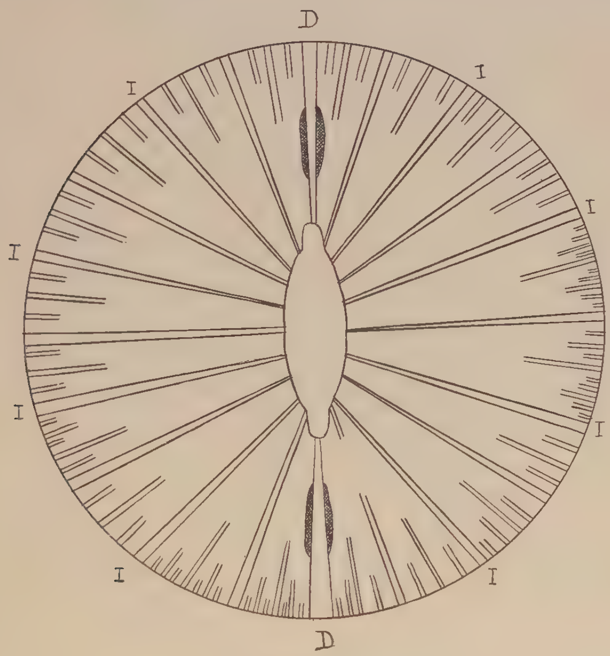

FIG. II.

the pairs of the older cycles; the other three occurred in the middle lateral interspace of the other side of the body, one of them intervening between the primary mesenteries on one side of the interspace and the succeeding member of the fourth cycle, while the other two alternated with the fourth cycle pair next the primary pair on the other side of the interspace. Finally in the individual with 104 pairs there are again four cycles regularly developed; in a primary interspace next one of the

directive pairs there are 8 pairs of a fifth cycle regularly arranged and in the interspace lateral to this there are two pairs of the fifth cycle. In each the two interspaces on the other side of the same directives there is a single pair of the fifth cycle, and in the middle lateral interspace of this same side of the body there are 8 pairs of the fifth cycle and in addition 6 representatives of a sixth cycle. The arrangement in this specimen is shown in the annexed figure, from which it may be seen that Carlgren's law that the mesenteries of the last cycle develop earliest in the interspaces adjoining the oldest pairs already present, is complied with.

The mesenteries of the first cycle are complete throughout the entire length of the stomatodæum; those of the second cycle are also complete, but are not attached so far down the stomatodæum as the members of the first cycle, while those of the third cycle reach the stomatodæum only in its uppermost part. The fourth, fifth and sixth cycles are incomplete. All the members of the first two cycles are sterile, the reproductive organs being borne apparently by the members of the third and fourth cycles. Both oral and marginal mesenterial stomata are present, the latter usually quite small.

Finally a word as to the synonymy of the West Coast specimens of *U. crassicornis*. As already stated, Verrill ('69) was the first to correctly identify this species from the West Coast of America, and he records its occurrence in Puget Sound, and in the Arctic Ocean north of Behring Straits, while Murdoch ('85), found it at Point Barrow. Verrill in his list of synonyms includes, with some doubt however, the *A. Laurentii* and the *A. elegantissima* of Brandt ('35) obtained in Behring Sea and at Sitka; Andres regards these two forms as being *species delendæ* on account of the insufficiency of their descriptions. I believe, however, that there are sufficient grounds for identifying the *A. Laurentii* with *U. crassicornis*, though I think Verrill was probably in error in likewise identifying the *A. elegantissima* with that species, since I have found in the present collection forms, described in preceding pages, which seem to agree with Brandt's description. I may say that I made an

endeavor to ascertain if any of the specimens collected by Mertens were still in existence, but the endeavor proved futile.

Genus Anthopleura, Duch. & Mich.

In 1860 Duchassaing & Michelotti established the genus Anthopleura for a Cribrinid characterized by possessing verrucæ arranged in longitudinal rows and with tentaculiform acrorhagi. In a later paper (**'64**) they added to the original single species, *A. Krebsi* upon which the genus was founded, other forms, one of which at least possessed lobed acrorhagi, altering at the same time the definition of the genus so that it became rather indefinite. In 1864 Verrill established a genus Aulactinia for a Cribrinid also possessing verrucæ arranged in longitudinal rows though becoming obsolete below and having prominent acrorhagi which were distinctly lobed. The later action of Duchassaing and Michelotti in including in their genus a form with lobed verrucæ led Verrill in 1869 to suggest the possibility of the identity of the two genera, but Andres (**'83**), going back to first principles, recognizes both, placing the forms with simple acrorhagi in the genus Anthopleura, while those in which they are distinctly lobed he refers to Aulactinia. Verrill in his most recent papers (**'99**) considers the two genera distinct and adds a third Bunodosoma to which he refers the *A. granulifera* of Lesueur and his *Bunodes cavernata*, and which he characterizes by possessing lobulated acrorhagi and verrucæ which are not adhesive.

It does not seem to me that the simplicity or lobulation of the acrorhagi is a feature worthy of generic importance when we find as much general similarity in such forms as *Aulactinia capitata*, *Anthopleura granulifera* and *Bunodosoma cavernata*, all of which forms I have had the opportunity of studying. As to whether the adhesiveness of the verrucæ may prove to be a feature of generic importance, I feel more uncertain, but at present am inclined to deny it that value.

The genus Ægeon described by Gosse (**'65**) seems to be undoubtedly identical with Aulactinia and need not be discussed.

I would then define the genus Anthopleura as follows :

Genus ANTHOPLEURA Duch. & Mich.

Synonyms.—Aulactinia, Verrill, 1864.
Ægeon, Gosse, 1865.
Bunodosoma, Verrill, 1899.

Cribrinidæ with true acrorhagi, usually with numerous perfect mesenteries, sphincter strong, column destitute of an epidermal covering and provided with verrucæ arranged more or less definitely in vertical series, tentacles simple.

5. *Anthopleura xanthogrammica* (Brandt)

Synonym.—Actinia (Taractostephanus) xanthogrammica, Brandt, 1835.

This species was found in only one locality, under the slaughter house at Port Townsend, but it occurred there in large numbers. An excellent figure of it is among the drawings kindly lent me by Mr. Agassiz, the individual figured having been obtained at San Francisco. Dr. Calkins states that evidences of multiplication by fission were not unfrequent among the Port Townsend specimens.

External Form.—The base is adherent. The column (**Pl. II, Fig. 17**) is provided with rows of tuberculiform verrucæ, to which particles of sand and small stones adhere and which are arranged in distinct vertical rows extending to the limbus as a rule, though in the upper part of the column shorter rows alternate with the longer ones. The margin is separated by a distinct though shallow fosse from the bases of the outermost tentacles, and from the margin of the outer wall of the fosse there project blunt processes, one of which corresponds to the summit of each row of verrucæ (**Fig. 19**, *a*, *c*). These are undoubtedly acrorhagi. They are much more distinct in some of the preserved individuals than in others and, indeed, may be more prominent at one portion of the margin than at another in the same individual, here appearing as mere hemispherical elevations and there as distinct blunt tentaculiform projections, or again having a distinctly lobed form.

The tentacles in the preserved specimens are very moderate in length, conical and rather obtusely pointed. In Mr. Agassiz's drawing they are represented however as rather long and slender,

while in that by Dr. Calkins they agree more with the condition in the preserved specimens. They are quite smooth and are arranged in about four cycles and are fairly numerous, though I did not succeed in making an accurate enumeration of them. The disk is smooth and somewhat concave and the peristome slightly elevated. The lips are ridged and there are two rather feebly marked gonidial grooves in the specimens examined.

Color.—Dr. Calkins describes the individuals obtained by him as being "crystalline" in appearance with "pink-tipped tentacles." The drawing which accompanied his notes (**Fig. 17**) shows the column, disk and bases of the tentacles to be faintly greenish-yellow, the tips of the tentacles being the only brightly colored portions of the animal. Mr. Agassiz's drawing, which is undoubtedly of the same species, represents the column as being of a bright green color, the disk of a dark olive green; this color extending upon the bases of the tentacles, being there succeeded by a yellow band, beyond which the tentacles are of a bright pink.

Size.—The preserved specimens sent me measured 1.0–1.5 cm. in height and about the same in diameter. Dr. Calkins states that the largest individuals "when expanded, measured fully three inches across the crown, but the average was much less."

Structure.—A longitudinal section of the column wall resembles closely what I have described and figured for *Cribrina elegantissima*. The tubercles differ from those of *Cribrina* only in the absence of a special development of endodermal muscles at their summits and in the presence of a distinct though fine band of nerve fibers in the basal portion of the modified ectoderm.

The sphincter is situated upon the floor of the fosse, just internal to the acrorhagi. It is oval in section and is of the pedunculate palmate variety (**Fig. 22**). The ectoderm of the acrorhagi is abundantly supplied with nematocysts, whereby they can readily be distinguished from tentacles in section. In these latter the longitudinal musculature is not imbedded in the mesoglœa and resembles in appearance that of *C. elegantissima*, as does also the radiating musculature of the disk, though here the

reticular arrangement of the mesoglœal processes cannot be distinguished as clearly as in that form.

The stomatodæum is longitudinally ridged and in the specimens examined was provided with two siphonoglyphes, which have the same structure as those of *C. elegantissima*.

The arrangement of the mesenteries is somewhat irregular. Apparently an hexamerous arrangement is the basis, the primaries, secondaries and tertiary cycles being perfect, the last to a less extent than the others. A fourth cycle is also present and is complete, but there are in addition representatives of a fifth and even of a sixth cycle irregularly distributed, a disturbance of the symmetry being thus produced.

Both the outer and inner stomata are present. The longitudinal musculature is well developed and in sections of the perfect mesenteries about half way down the column terminates at its outer edge in a strong process from which lateral lamellæ arise (**Fig. 23**). Lower down this arrangement is not apparent, the muscle processes diminishing in size toward each edge of the muscle area. The parieto-basilar (**Fig. 24**) is well developed, forming a marked fold. The basilar muscle (**Fig. 25**) is fairly well developed, resembling somewhat that of *C. artemisia*, though smaller in accordance with the smaller size of the specimens. The tertiary mesenteries are all fertile, and, in addition, reproductive organs occur on some of the mesenteries of the fourth cycle.

The identification of this species with Brandt's *Actinia xanthogrammica* is suggested in the memoranda accompanying Mr. Agassiz' drawing, and though Brandt makes no mention of the conspicuously pink-tipped tentacles yet it is quite possible, indeed probable, that this is the proper identification, as it is evident that the coloration of the species may vary considerably.

I was for a time inclined to identify it with Verrill's *Anthopleura Dowii*, but hesitate to do so on account of the geographical distribution of that form and the absence of data as to its internal structure. It is evidently a highly variable species, so far as its coloration is concerned, and it may be noted that a specimen from Acajutla is described as having the

tips of the tentacles "dark red." For the present, however, it seems advisable to regard it as distinct from the present form, but I may point out that the form described by Fewkes from Santa Barbara as *Bunodes californica* is in all probability assignable to Verrill's species.

Genus Epiactis, Verrill.

This genus was established by Verrill in 1869 for the reception of a form from Puget Sound which was characterized by having the young adherent to the outer surface of the column. In 1899 Verrill published a brief description of the structural peculiarities of the type, referring it to the family Cribrinidæ (Bunodactidæ) on account of its possession of a circumscribed endodermal sphincter.

It seems doubtful whether the fact that the young adhere to the column wall is sufficient for the establishment of a distinct genus, but in other respects *E. prolifera* seems to be sufficiently distinct from other Cribrinids to warrant the retention of the genus. It is one of the smooth-walled genera and differs from Leiotealia (Hertwig, '**82**) in the form of the sphincter and of the muscle pennon, while from Isotealia (Carlgren, '**99**) it is distinguished by the absence of pseudoacrorhagi.[1]

6. *Epiactis prolifera*, Verrill.

Synonyms.—Epiactis prolifera, Verrill, 1869[a].
Epiactis fertilis, Andres, 1883.

The specimens in the collection were found growing upon the weeds and water grasses at Hadlock Harbor, Puget Sound.

External Form (**Fig. 25**).—The base is adherent. The column is marked by longitudinal grooves and more distinctly with transverse grooves and wrinkles, probably due to contraction,

[1] I am inclined to agree with Carlgren ('**99**) that the form I described ('**93**) as *Leiotealia badia* is identical with his *Isotealia antarctica*. In looking over my preparations I notice that in some of the sections the sphincter is decidedly nearer the margin than it is in others, though in all it is the same distance above the floor of the fosse. This seems to indicate the existence of the pseudoacrorhagi which Carlgren describes. But, since my preparations were made from a small portion of a single highly contracted individual, it seems preferable to await a reëxamination of the type, now in the U. S. National Museum, before deciding the question.

but otherwise it is smooth and is unprovided with verrucæ or tubercles. In two of the specimens embryos were adherent to the surface, and appeared as small, oval, pale bodies, in one specimen arranged in a single incomplete and interrupted circle a short distance above the limbus, a few lying a short distance above this circle in one part of the circumference, while a single one was attached high up on the column wall not far from the margin (**Fig. 28**, *Em.*). In the second specimen but one embryo occurred, situated a short distance below the margin.

The margin is quite distinct, but smooth, except for wrinkles produced by contraction, and it is separated by a slight fosse from the bases of the outer tentacles. The tentacles are moderately long and acuminate and are distinctly entacmæous. I did not succeed in making a satisfactory enumeration of them, but they are fairly numerous and appear to be arranged in five or six cycles.

The disk in the only specimen in which it could be seen was of slight extent and concave. The peristome is prominent and the lips grooved. Two gonidial grooves were distinguishable.

Color.—According to Dr. Calkins' description the color is a "bright grass green or weed green" striped with darker green. Verrill apparently had no notes of the coloration of the specimens he studied, but among the drawings loaned me by Mr. Agassiz I find two which apparently represent this species. One is undoubtedly identical though it has no embryos adherent. The column is represented as bright grass green marked with longitudinal streaks of dark brown. The disk is very dark green with numerous radiating stripes of cream white and the tentacles are buff with a distinct dark greenish-brown spot at the base of each. This specimen was obtained at Crescent City. The other specimen is less certainly identical though having the same general external form. The column is dark brown streaked longitudinally with lighter brown and the tentacles are a dull grayish green. This specimen was obtained at San Rosario.

Size.—The living specimens measure from 1.2 to 2.5 cm. in diameter and the largest about 1.2 cm. in height. The preserved

individuals measure 1 cm. on the average in height and about 1.2 cm. in diameter, the base being in all cases somewhat larger than the column. Verrill's measurements of preserved specimens are identical with those just given. The tentacles in the most expanded form I examined measured 1.3 cm. in length but in others they were only about half that length.

Structure.—The column mesoglœa is thin and of a fibrous structure and its inner surface bears a well-developed layer of simple muscle processes. The inner ends of the endoderm cells are heavily laden with dense, black pigment. At the margin the endodermal musculature becomes considerably lower and on the inner wall of the fosse there is situated the sphincter. In the first individual I examined this had the form shown in **Fig. 26** and was situated on the outer wall of the fosse, and from its general appearance I was led to regard it as being mesoglœal and so referred the species to the family Paractidæ. The publication of Verrill's description (**'99**) of the structure of the type and correspondence which I had with him on the subject induce me to examine the sphincter in other individuals and in these I found perfect agreement with what Verrill had described. The sphincter is of the circumscribed sessile form, situated upon the inner wall of the fosse, and has an almost circular form in cross-section; the mesoglœal lamellæ which compose it are rather fine and anastomose more or less in places. It was evident then that the first individual that I examined either had an abnormal sphincter or else belonged to a different species from the others. The latter possibility seems very improbable on account of the complete similarity in other respects and I conclude that the former one is correct. An extension of the area of attachment of the sphincter and a greater development of anastomoses of the lamellæ would readily convert the normal sphincter into the condition shown in **Fig. 26.**[1]

[1] This figure is, accordingly, of interest only as representing an abnormality. The plates were unfortunately in process of reproduction before I perceived the error into which I had fallen and it was not possible, therefore, to replace the figure by a represention of the normal sphincter.

I may add that Mr. H. B. Torrey has recently informed me that in all the specimens of *E. prolifera* which he has examined, the sphincter was of the circumscribed sessile type.

In **Fig. 27** is represented a section through a portion of the column wall bearing one of the embryos. It shows that the embryos are in an early stage of development, having just reached the stage at which the stomatodæum (*st*) is being invaginated. The ectoderm of the embryo (*e. ec*) forms a continuous sheet completely separated at every point from the ectoderm of the parent (*ec*) on which it rests, and it is evident that the embryos are not buds, but really egg-embryos which have become attached to the surface of the adult actinian and are held there by the mucus (*m*) secreted by the numerous ectodermal gland cells.

In the specimens which Verrill (**'69**) originally examined and which he has recently figured (**'99**) the attached embryos had reached a much more advanced stage of development than those just described, the smallest one having twelve tentacles and the largest twenty-four. Verrill seemed inclined, in his earlier paper, to regard the embryos as buds and states that they "probably derive nutriment from the parent." In his more recent account he evidently recedes somewhat from this position and I may point out that it seems clear from what I have stated above as to the distinct separation of the embryos from the parent that they are not nourished by the parent in the sense that there is any communication between the cavities of the parent and those of the embryos.

The tentacles are thin-walled and their ectodermal musculature is but feebly developed. The radial musculature of the disk is fairly strong in its peripheral portions, but more centrally it is very feeble ; it is throughout ectodermal.

In the region of the lips the mesoglœa becomes considerably thickened forming ridges corresponding to the ridges of the stomatodæum. Occasionally, though not always, the tip of one of the thickenings seems to be separated from its main portion by a slight interval, producing a minute tubercle immediately external to the lips. The stomatodæum is ridged and

there are two siphonoglyphes, one of which is much deeper than the other.

The mesenteries are arranged in four cycles with occasional representatives of a fifth. Twelve pairs are perfect in the upper part of the body, but a little farther down, even above the middle of the body, only the six primary pairs reach the stomatodæum. There are two pairs of directives.

The longitudinal musculature of the mesenteries (**Fig. 28**) is fairly well developed, but possesses no special features of interest; it gradually tapers off towards both edges and occupies about half the muscular portion of the mesentery at the level of the middle of the stomatodæum. The parieto-basilar in its lower part does not form a special fold, but consists of a number of processes arising directly from the surface of the outer portions of the mesenteries, but above a slight fold is visible in some of the mesenteries as shown in **Fig. 28**. The basilar muscle has the appearance represented in **Fig. 29**. All the mesenteries, with the exception of those of the first and fifth cycles, are gonophoric.

UNIVERSITY OF MICHIGAN, February 22, 1901.

LITERATURE

Andres, A.
'83 Le Attinie
Fauna u. Flora des Golfes von Neapel. Monogr. XI. 1883

Brandt, J. F.
'35 Prodromus descriptionis animalium ab H. Mertensio observatorum. 1835

Carlgren, O.
'93 Studien über Nordische Actinien. I
Kongl. Svensk. Vet. Akad. Handl., XXV. 1893

Carlgren, O.
'99 Zoantharien. Hamburger Magalhaenische Sammelreise. Hamburg. 1899

Couthouy, J. P.
'38 Descriptions of new species of Mollusca and Shells, and remarks on several Polyps found in Massachusetts Bay
Boston Journ. Nat. Hist., II. 1838

Cunningham, J. T.
'89 Tealia tuberculata, a study in Synonomy
Journ. Marine Biolog. Assoc., N. S., I. 1889

Dana, J. D.
'46 Zoophytes. United States Exploring Expedition. Philadelphia. 1846

Dawson, J. W.
'58 On Sea-Anemones and Hydroid Polyps from the Gulf of St. Lawrence
Canadian Naturalist and Geologist, III. 1858

Dicquemare, J. F.
'73 An Essay towards Elucidating the History of the Sea-Anemones
Phil. Trans., LXIII. 1773.

Dixon, G. Y., and A. F.
'89 Notes on Bunodes thallia, Bunodes verrucosa and Tealia crassicornis
Sci. Proc. Roy. Dublin Soc., N. S., VI. 1889

Duchassaing, P., and Michelotti, G.
'60 Mémoire sur les Coralliaires des Antilles
Mém. Acad. Sci. Torino, Sér. II, XIX. 1860

Duchassaing, P., and Michelotti, G.
'64 Supplement au Mémoire sur les Coralliaires des Antilles.
Mém. Acad. Sci. Torino, Sér. II, XXIII. 1864

Duerden, J. E.
'95 On the genus Alicia (Cladactis), with an anatomical description of *A. Costae* Panc.
Ann. and Mag. Nat. Hist., Ser. 6, XV. 1895.

Duerden, J. E.
'97 The Actiniarian Family Aliciidæ
Ann. and Mag. Nat. Hist., Ser. 6, XX. 1897

Ehrenberg
'34 Die Corallenthiere des rothen Meeres physiologisch untersucht und systematisch verzeichnet. Berlin. 1834

Fewkes, J. W.
'89 New Invertebrata from the Coast of California. Boston. 1889

Gosse, P. H.
'55 On Peachia hastata, with observations on the family of Actiniadæ
Trans. Linnean Soc., XXI. 1855

Gosse, P. H.
'60 Actinologia Britannica. London. 1860

Haddon, A. C.
'89 A Revision of the British Actiniæ. Part I
Sci. Trans. Roy. Dublin Soc. Ser. 2, IV. 1889

Von Heider, A.
'77 Sagartia troglodytes, ein Beitrag zur Anatomie der Actinien
Sitzber. K. Acad. Wien. Math.-Nat. Cl., LXXV. 1877

Hertwig, O. & R.
'79 Die Actinien. Jena. 1879

Hertwig, R.
'82 Report of the Actiniaria
Report on the Sci. Results of the Voyage of H. M. S. Challenger. Zool. Part XV. 1882

Hertwig, R.
'88 Supplement to the Report on the Actiniaria
Report on the Sci. Results of the Voyage of H. M. S. Challenger. Zool. Part LXXIII. 1888

Jourdan, E.
'80 Recherches Zoologiques et histologiques sur les Zoanthaires du Golfe de Marseilles
Am. Sci. Nat. Zool., 6me sér., X. 1880

McMurrich, J. P.
'89 The Actiniaria of the Bahama Islands, W. I.
Journ. of Morph., III. 1889.

McMurrich, J. P.
'90 Contributions on the Morphology of the Actinozoa. I. The Structure of Cerianthus Americanus
Journ. of Morph., IV. 1890

McMurrich, J. P.
'93 Report on the Actiniæ collected by the U. S. Fish Commission Steamer Albatross during the winter of 1887–88
Proc. U. S. Natl. Museum, XVI. 1893

McMurrich, J. P.
'97 Contributions on the Morphology of the Actinozoa. IV
Zoolog. Bull., I. 1897

Murdock, J.
'85 Marine Invertebrata in Report of the International Polar Expedition to Point Barrow, Alaska. Washington. 1885

Parker, G. H.
'97 The mesenteries and siphonoglyphs in Metridium marginatum, Milne-Edwards.
Bull. Mus. Comp. Zool., XXX. 1897

Teale, T. P.
'37 On the Anatomy of Actinia coriacea
Trans. Phil. Soc. Leeds, I. 1837

Thorell, T.
'58 Om den inre byggnaden af Actinia plumosa Müll.
Ofvers. K. Vet. Akad. Förh. Stockholm, XV. 1858

Tilesius, G. T.
'09 De nova actiniarum specie gigantea Kamtschatica
Mém. Acad. Imp. St. Petersbourg, I. 1809

Verrill, A. E.
'64 Revision of the Polypi of the Eastern Coast of the United States.
Mem. Boston Soc. Nat. Hist., I. 1864

Verrill, A. E.
'65 Classification of Polyps
Proc. Essex Inst., IV. 1865

Verrill, A. E.
'69 Synopsis of the Polyps and Corals of the North Pacific Exploring Expedition
Proc. Essex Inst., VI. 1869

Verrill, A. E.
'69a Review of the Corals and Polyps of the West Coast of America
Trans. Connecticut Acad. Arts and Sci., I. 1869

Verrill, A. E.
'99 Descriptions of imperfectly known and new Actinians, with critical notes on other species
Amer. Journ. Sci., VII. 1899

PLATE I.

PLATE I.

Fig. 1. Transverse section of sphincter of a specimen of *Metridium dianthus* measuring 1.5 cm. in height (Leitz I, 3, camera).

2. Transverse section of sphincter of a specimen of *Metridium dianthus* measuring 8 cm. in height (Leitz I, 3, camera).

3. Transverse section of sphincter of a specimen of *Metridium dianthus* measuring 3 cm. in height (Leitz I, 3, camera).

4. Transverse section of a mesentery of the first cycle of *Metridium dianthus* (Zeiss a, Leitz I, camera).

5. Transverse section of a directive mesentery of *Metridium dianthus* (Leitz I, 3, camera).

6. Transverse section of sphincter of *Urticina crassicornis* Leitz I, Zeiss a, camera).

7. *Cribrina elegantissima*, from a preserved specimen. Natural size.

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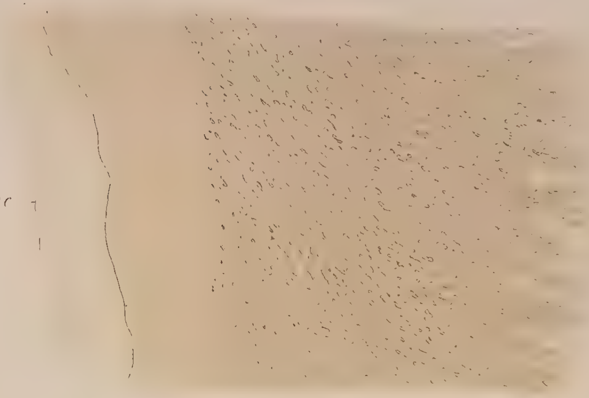

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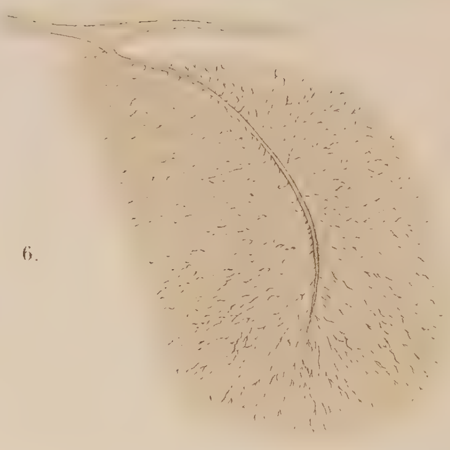

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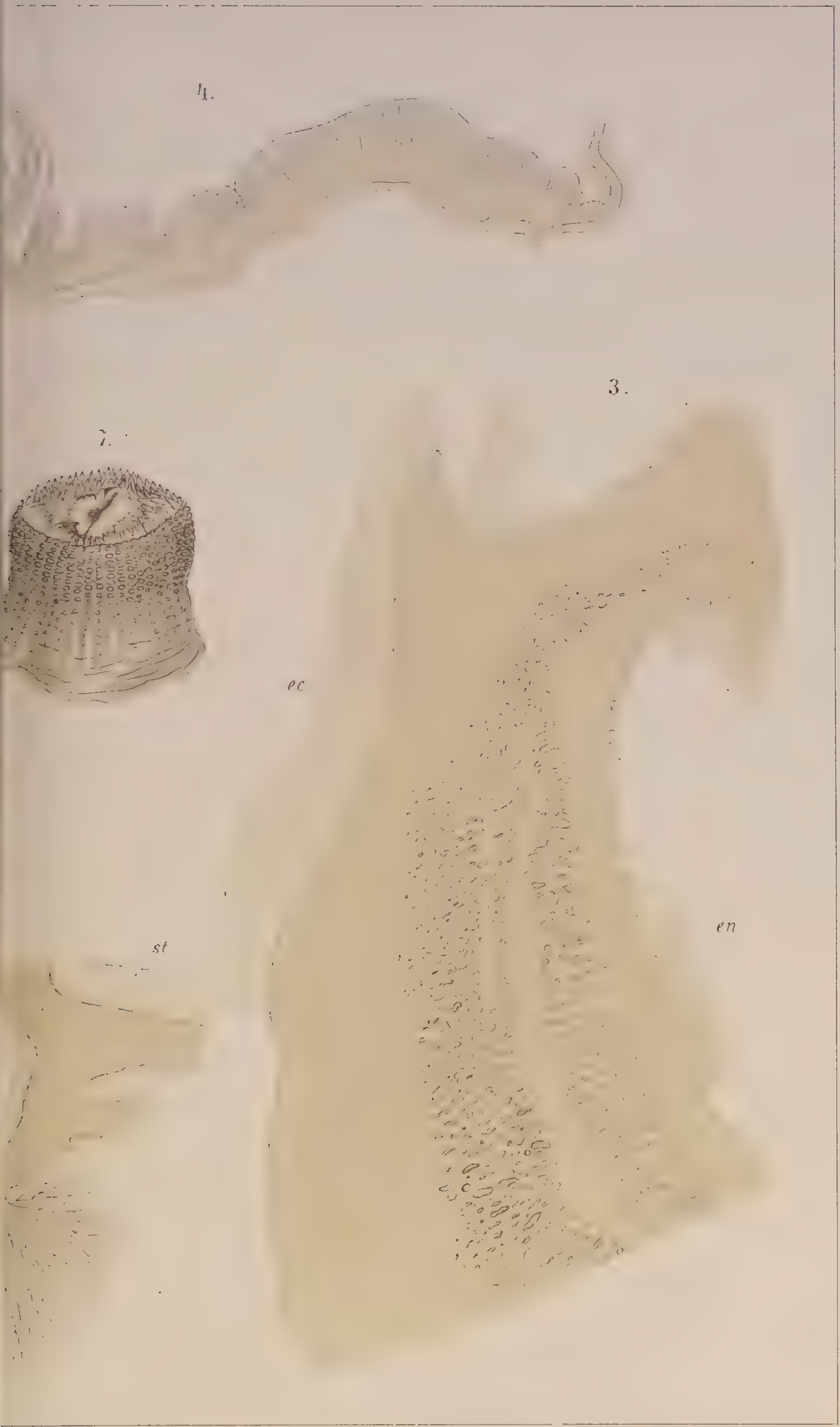
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PLATE II.

PLATE II.

Fig. 8. *Cribrina elegantissima* (drawn by Dr. G. N. Calkins).

9. Longitudinal section of upper part of the column wall of *Cribrina elegantissima*. *cm* = circular muscle at apex of verruca; *ec* = column ectoderm; *en* = column endoderm; *ve* = modified epithelium at the apex of the verruca (Leitz I, 3, camera).

10. Transverse section of sphincter of *Cribrina elegantissima* (Leitz I, 3, camera).

11. Tangential section of disk of *Cribrina elegantissima* (Leitz I, 3, camera).

12. Transverse section of tentacle of *Cribrina elegantissima* (Leitz I, 3, camera).

13. Transverse section of siphonoglyphe of *Cribrina elegantissima* (Zeiss a, Leitz I, camera).

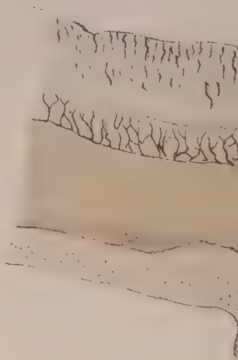
14. Transverse section of perfect mesentery of *Cribrina elegantissima* (Zeitz a, Leitz I, camera).

15. *Cribrina artemisia* from a preserved specimen. Natural size.

16. Transverse section of *Cribrina artemisia* (Zeiss a, Leitz I, camera).

17. *Anthopleura xanthogrammica* (drawn by Dr. G. N. Calkins.

8.



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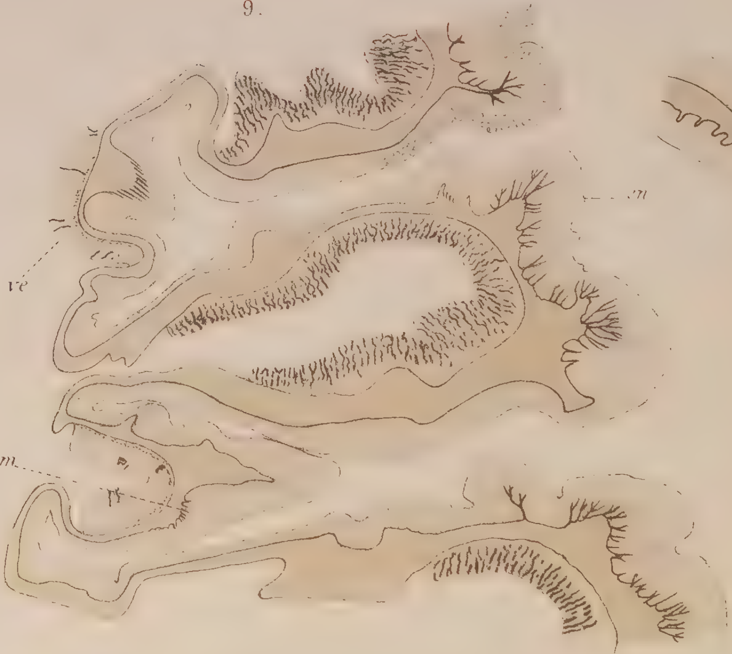

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G. N. C. & J. P. McM. DEL.

PLATE II.

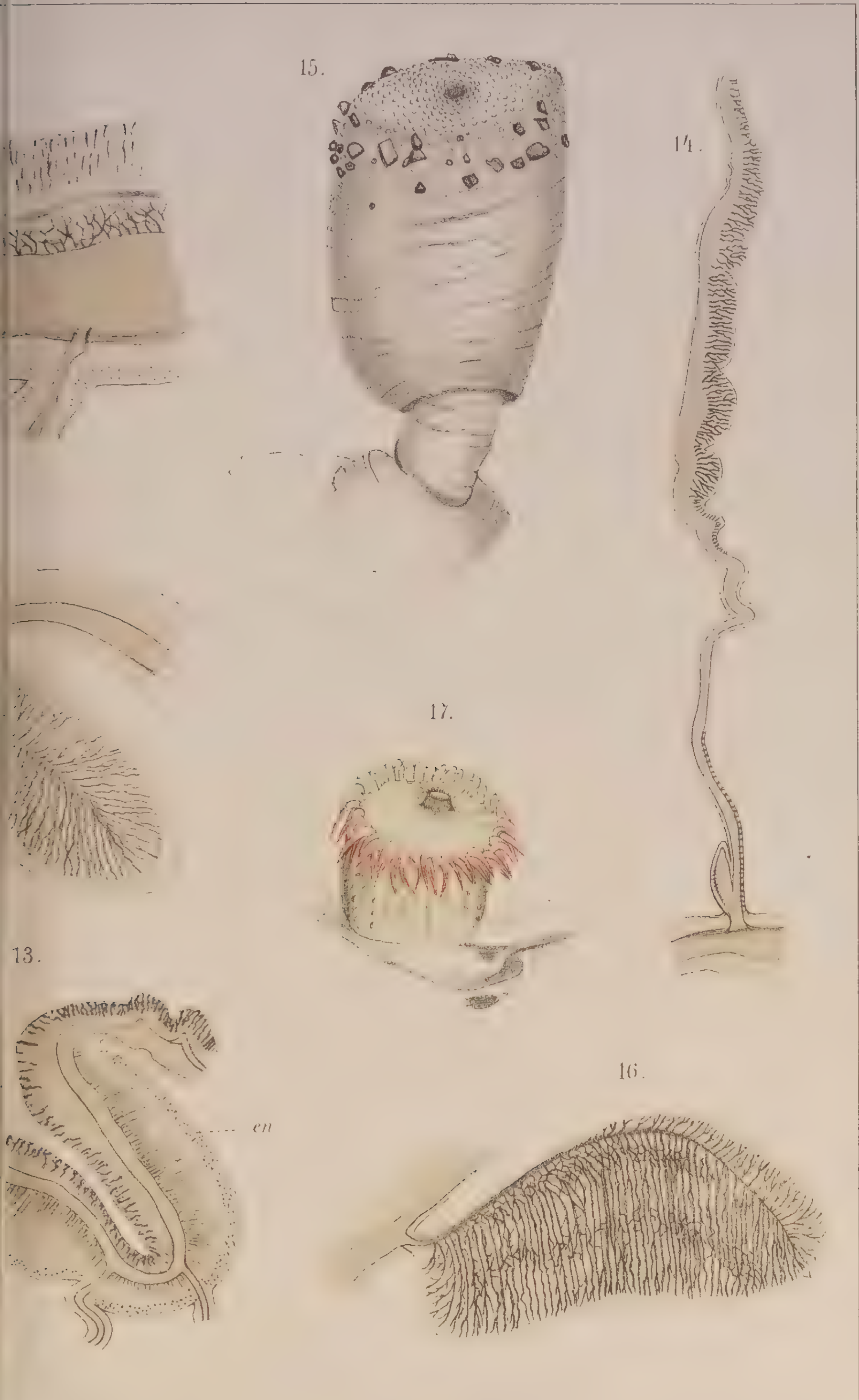

PLATE III.

PLATE III.

18. Tangential section of disk of *Cribrina artemisia* (Leitz I, 3, camera).
19. Transverse section of perfect mesentery of *Cribrina artemisia* (Leitz I, 3, camera).
20. Transverse section of basilar muscle of *Cribrina artemisia* (Leitz I, 3, camera).
21. Portion of upper part of a perfect mesentery, with disk, margin, and upper part of column in section, of *Anthopleura xanthogrammica*; *ac* = acrorhagus; *sp* = sphincter; *t* = tentacle. (× 6.)
22. Transverse section of sphincter of *Anthopleura xanthogrammica* (Leitz I, 3, camera).
23. Transverse section of primary mesentery of *Anthopleura xanthogrammica* (Zeiss a, Leitz IV, camera).
24. Transverse section of basilar muscle of *Anthopleura xanthogrammica* (Leitz I, 3, camera).
25. *Epiactis prolifera* from a preserved specimen. *Em* = adherent embryo (nat. size).
26. Transverse section of sphincter of *Epiactis prolifera*. *L* = lower extremity of section; *U* = upper extremity. (Leitz I, 3, camera).
27. Transverse section of a portion of the column wall of *Epiactis prolifera*, with an adherent embryo. *Ec* = column ectoderm; *E.ec* = ectoderm of embryo; *E.en* = endoderm of embryo; *M* = mucus; *St* = stomatodæal invagination. (Leitz I, 3, camera).
28. Transverse section of perfect mesentery of *Epiactis prolifera*. (Zeiss a, Leitz II, camera).
29. Transverse section of basilar muscle of *Epiactis prolifera* (Leitz I, 3, camera).

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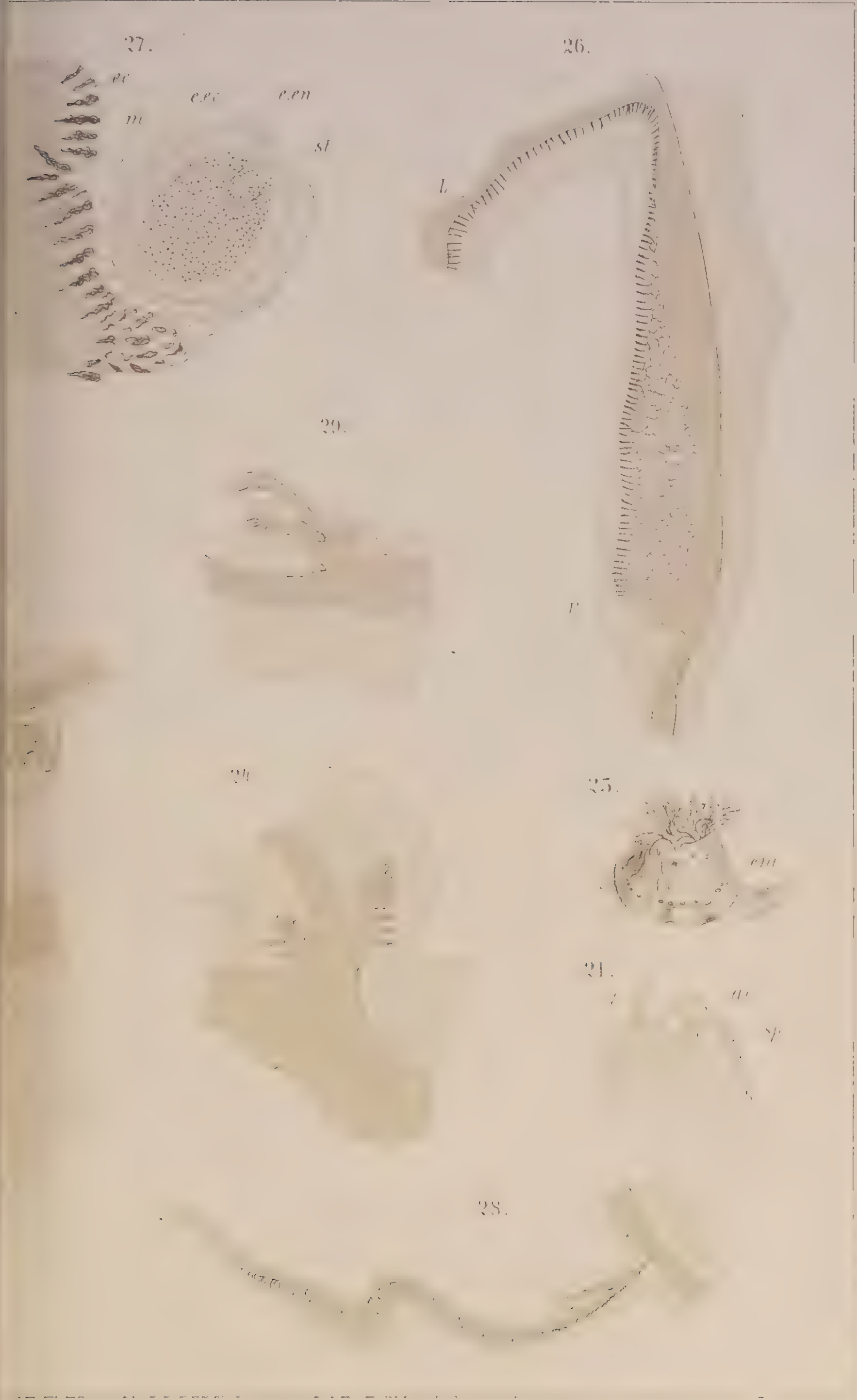
J. P. McM. DEL.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26.
ec
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28.

[ANNALS N. Y. ACAD. SCI., Vol. XIV, No. 2, pp. 53–66, June 5, 1901.]

THE MORPHOLOGICAL SIGNIFICANCE OF CERTAIN PERICLAVICULAR SUPERNUMERARY MUSCLES

WITH A REPORT OF A NEW M. SUPRACLAVICULARIS PROPRIUS POSTERIOR

GEO. S. HUNTINGTON

[Plates IV–V.]

(Read February 12, 1900)

Among the muscular variations of the human pectoral girdle the group of periclavicular supernumerary muscles possesses a peculiar morphological interest, by reason of the complex myological character of the region involved and the importance of correctly interpreting the significance of the variant conditions.

The abnormal muscle, of which this paper treats, is now described and figured for the first time as the *M. supraclavicularis proprius posterior.* It was found as a nearly symmetrical bilateral muscular slip in a male subject, of German birth, 43 years of age, arising by a slender tendon from the upper surface of the sternal extremity of the clavicle, under cover of the sterno-cleido-mastoid and extending laterad across the supraclavicular fossa to be inserted behind the clavicular attachment of the trapezius into the superior surface of the acromial end of the clavicle by a narrow tendon which on the left side can be followed nearly to the extremity of the bone.

SUPERNUMERARY CLAVICULAR MUSCLES

The nearest approach to the conditions presented by this variant muscle—*as regards the attachment by both extremities to the clavicle*—is afforded by a group of supernumerary clavicular muscles, of which five instances have been recorded, possessing the following common characters: Origin from the

sternal extremity of the clavicle, *ventrad* to the clavicular attachment of the sterno-cleido-mastoid. The muscle, fleshy in the middle and tendinous at either end, passes laterad, above the clavicle, inserting at the acromial end of the bone, between the trapezius and the deltoid.

Wenzel Gruber described the first of these instances under the name of *M. supra-clavicularis proprius, s. præclavicularis subcutaneus*, in 1865, in Reichert's Archiv, p. 703. The same author subsequently in 1877 observed a second instance of the variation which is recorded in Virchow's Archiv, Vol. LXXII, p. 496. Bardeleben has recorded an example of the muscle in the "Sitzungsberichte d. Jenaischen Gesellschaft für Med. und Naturwiss.," March, 1877.

Knott (Jour. Anat. and Phys., Vol. XV, p. 139) observed the fourth case, which he reports as *M. supraclavicularis proprius, vel. Tensor fasciæ colli* (Gruber). The muscle in this instance had a medial attachment in front of the clavicular head of the sterno-cleido-mastoid, about 1¾″ outside the sterno-clavicular articulation, while the lateral extremity, at a distance of about 2″ from the acromial end of the bone, had a somewhat broader attachment in front of the trapezius. The muscle was enclosed in a sheath formed by the deep cervical fascia, a condition also noted in Gruber's cases, whence this author defines the muscle as a "Tensor of the cervical fascia."

Dubar (Soc. Anat. Paris, 1880) described a "muscle ansiform sus-claviculaire" which presented the same connection with the clavicle at both ends and was enclosed in a sheath derived from the cervical fascia.

While the clavicular attachments of these five muscles agree with those of the variation above described, their position *ventrad* of sterno-cleido-mastoid and trapezius differentiates them sharply from the muscle here under consideration whose course is dorsad to both. I consider this *superficial* position of the *supraclavicularis proprius* of Gruber and of the other authors quoted, as determining the definite relationship of the five variations recorded to the other members of the *præclavicular* group of supernumerary muscles. In spite of the similarity of attach-

ment to both extremities of the clavicle the muscle described in this paper belongs to the *retro-clavicular group* and possesses hence an entirely different morphological significance. The following instances have been observed of supraclavicular muscles situated behind the sterno-cleido-mastoid and trapezius.

M. J. WEBER (Vollständiges Handbuch der Anatomie des Menschlichen Körpers (Zergliederungs-Kunde und Kunst), I Bd., Bonn, 1839, p. 560) says:

"I have observed once a variation, remarkable on account of the analogy of the clavicles and ribs, and of the subclavius with the intercostals, in which from the posterior surface of the manubrium sterni to the post. surfaces of the sternal ends of both clavicles a fairly strong semicircular flat muscle passed which could depress the clavicles down and in."

LAWSON TAIT (Journ. of Anat. and Phys., p. 237) described a muscle arising by two heads, one from the posterior surface of the manubrium sterni at its junction with the cartilage of the first rib, the other from the posterior edge of the first rib itself. It lay on the brachiocephalic trunk, on the lower thyroid veins and the scalenus anticus, and was inserted into the clavicle, along the posterior border of the bone, at the inner margin of the insertion of the trapezius.

KNOTT is quoted as having observed a muscle identical in all respects with that described by TAIT.

These two instances of WEBER and TAIT are quoted by most authors treating of the periclavicular supernumerary muscles under the name of *M. retroclavicularis* or *sternoclavicularis posterior*. MACALISTER ("Additional Observations on Muscular Anomalies in Human Anatomy (Third series), with a catalogue of the principal muscular variations hitherto published," Trans. Royal Irish Acad., Vol. XXV, Pt. I, Dublin, 1872, p. 51) quotes Weber's and Tait's cases as instances of the "M. retroclavicularis" and adds concerning the latter's case: "This is much rarer than the foregoing (M. supraclavicularis of Luschka and Haller, cf. infra), and is probably only a form of the M. supraclavicularis given above."

Both TESTUT ("Les anomalies musculaires chez l'homme,"

Paris, 1884, p. 55) and Le Double ("Traité des variations du système musculaire de l'homme," Tome I, Paris, 1897, p. 266) quote Weber's and Tait's cases—under the name of "*M. retro-clavicularis*" or "*Sterno-clavicularis posterior*"—without adding any new instances of the variation.

In the interests of a consistent terminology it would appear advisable to describe Weber's case as a "*M. sterno-clavicularis posterior*," Tait's instance as "*M. chondro-sterno-clavicularis posterior*," the five cases of superficial muscles above quoted as examples of the "*M. supra-clavicularis proprius anterior*" and the muscles here described as "*M. supra-clavicularis proprius posterior*."

MORPHOLOGICAL SIGNIFICANCE

To establish the morphological significance of the muscle in question, the following facts deserve consideration: Gruber ("Die Supernumerären Brustmuskeln des Menschen," Mém. de l'Acad. Imp. des Sciences des St. Pétersbourg, VII Serie, Tome III, No. 2, 1860, pp. 3 and 6) describes a "*M. sterno-clavicularis superior, seu supraclavicularis*," as arising from the manubrium sterni above and behind the origin of the sternal head of the sterno-cleido-mastoid, from the margin of the clavicular incisure and in some cases also from the margin of the semilunar incisure. The muscle passes upward and outward, over the sterno-clavicular capsule, behind the clavicular head of the sterno-cleido-mastoid, to be inserted into the posterior surface of the clavicle between "the beginning of the second and third fifth of the bone." Gruber found this muscle five times in 100 subjects, four adult males and one boy. Twice it was bilateral, twice present only on one side (right) and in one case only on the left side. He figures an instance of the variation (loc. cit., Taf. I, fig. 4).

A number of other anatomists have observed and described the muscle, beginning with Haller, in 1766 ("Elem. physiol.," Tome III, p. 46, Lausanne, 1766). Luschka ("Ein M. Supra-clavicularis beim Menschen," Müller's Archiv, 1856, p.

282) describes and figures a supra-clavicular muscle as arising from the middle of the posterior surface of the clavicle and passing over the sternal end of the bone to be inserted into the manubrium sterni just below the inter-clavicular ligament. Luschka suggests a relation between this muscle and the ossa suprasternalia.

He found the muscle three times in male subjects, once bilateral, twice only on one side. Later (quoted from Gruber, loc. cit., p. 4) Luschka encountered four additional instances of the muscle.

HYRTL ("Zwei Varianten des M. Sterno-clavicularis," Sitzber. d. Math. naturw. cl. d. Kais. Akad. der Wiss., Bd. XXIX, Wien, 1858, p. 265) describes Luschka's supra-clavicularis as "M. sterno-clavicularis" in six subjects out of 83, 5 men and 1 woman. In four of these (3 bilateral, 1 on left side) the muscle corresponded to Luschka's description. The two remaining cases Hyrtl regards as variations of the same muscle. The first variation (subject æt. 30) consisted of a tendinous bundle, arising from the manubrium sterni at the level of its junction with the body, which ascended to the jugular notch and divided into two diverging transverse bundles, which, becoming muscular, passed over the sterno-clavicular joint, behind the clavicular head of the sterno-cleido-mastoid, to the clavicle. The second variation appeared as an *inter-clavicular* muscle, a flat transverse band uniting the sternal extremities of both clavicles lying upon the inter-clavicular ligament above the upper margin of the manubrium. The muscle was attached to the sterno-clavicular capsule between the inter-clavicular and sterno-clavicular ligaments and to the intra-articular cartilage of the joint. Hyrtl regards this variation as derived from the first by suppression of the median tendon of origin from the manubrium and by arched fusion of the two muscular bellies thus detached across the median line.

Other instances of the *M. supraclavicularis* or *sternoclavicularis superior* are recorded by Retzius ("Hygeia," 1856, Bd. 18, p. 649), Hellema (Geneeskundig Tijdschieft, 5 Jahrg., I Afd.) and Macalister (loc. cit., p. 50). I have observed 13 examples of the muscle.

If the muscle forming the subject of this communication is compared with the typical *supraclavicularis* or *sternoclavicularis superior* it will appear that the lateral attachment and the relation to the clavicular head of the sterno-cleido-mastoid of both agree. In our *M. supraclavicularis proprius posterior* the lateral extremity of the muscle is attached to the posterior surface of the clavicle, and it attains this position by passing dorsad of the clavicular head of the sterno-cleido-mastoid. The same arrangement obtains in those instances of the typical *sternoclavicularis* in which the muscle extends further laterad than is usually the case (Retzius' example, outer third of clavicle), although in the majority of recorded cases the typical *sternoclavicular* muscle is short, not extending beyond the inner third of the clavicle. That the lateral end of the muscle here under consideration extended beyond and behind the trapezius to the acromial end of the clavicle is therefore unusual when compared with the typical arrangement of the *sternoclavicularis*, but it brings the entire group, to which both muscles belong, into harmony with other muscular variations which serve to satisfactorily explain the significance of the aberrant condition.

The mesal extremity of the muscle herein described differs at first sight radically from the typical *sternoclavicularis*. The mesal tendon is attached behind the sterno-cleido-mastoid to the posterior and upper border of the sternal extremity of the clavicle, but entirely confined to that bone, not extending to the sterno-clavicular capsule or to the manubrium. In contrast to this arrangement the mesal tendon in the great majority of the typical *sternoclaviculares* occupies a more ventral position, being attached above and in front of the sterno-clavicular articulation to the manubrium.

If, however, this typical arrangement of the mesal tendon of the usual *sternoclavicularis* is compared with the variations reported by Hyrtl, and with the cases described by Weber and Tait, it will be seen that a series, depending upon regression of the sternal extremity of the common form of the variant muscle, can be established, leading from the usual type, through three

stages, to the conditions found in our *M. supraclavicularis proprius posterior.* In Hyrtl's first recorded case the beginning loss of the sternal attachment is signalized by the single median tendon which connects the two muscles with the manubrium. In his second variation the muscles have largely given up the manubrial attachment and have fused into an inter-clavicular muscle. Separation of the inter-clavicular muscle in the median line into its original components, and further regression of each laterad would lead to the arrangement described in Weber's case, while Tait's case only differs in having an additional attachment to the posterior margin at the first rib, which is likely to be acquired in the course of migration. Lastly, in our instance, the mesal extremity of the muscle has lost all connection with the sternum, the episternal (inter-clavicular) structures and the sterno-clavicular articulation and has acquired a purely clavicular attachment. We may, therefore, be justified in regarding the typical sterno-clavicularis as the antecedent of the mesal extremity of the three supra- or retro-clavicular muscles heretofore recorded, the condition presented by our case being the final stage in a progressive migration of the mesal tendon of the muscle from the sternum successively to the inter-clavicular ligament, the capsule of the sterno-clavicular articulation and finally to the posterior surface of the clavicle.

Turning to the lateral termination of the muscle under consideration and examining cognate variations in order to determine its significance, we have to consider in the first place, a group of aberrant muscles extending between the upper border of the scapula and the clavicle.

The *M. scapulo-clavicularis*, or *coraco-clavicularis* has in several instances been observed to extend as a muscular slip between the superior border of the scapula, or the transverse ligament, or base of coracoid process, and the posterior border or inferior surface of the clavicle, passing behind the clavicular attachments of the trapezius and sterno-mastoid.

Moreover, a human muscular variation, described by Wood, Gruber, Hellema, Curnow, Reid and Taylor, Shepherd, and

Brown, the *M. sterno-chondro-scapularis*, corresponding to a muscle normally encountered in many mammalia, is found not very uncommonly, extending between manubrium of the sternum, or the first rib or its cartilage and the upper border of the scapula, usually near the suprascapular notch or the base of the coracoid process. This aberrant muscle passes behind the normal subclavius, when that muscle is present, while in other cases the typical subclavius is absent and is replaced by the abnormal muscle.

Considering the relationship of the subclavius insertion to the coraco-clavicular ligaments and to the coracoid process of the scapula it is not a very farfetched view to regard the normal human subclavius muscle as a derivative from the mammalian sterno-chondro-scapular sheet, which has lost its scapular attachment, and receded to the inferior surface of the clavicle, while its original distal portion, metamorphosed into fibrous tissue, remains as the coraco-clavicular ligaments.

Again the whole group of retro-clavicular supernumerary muscles are properly to be referred to the same mammalian sterno-chondro-scapular muscular sheet of which they represent myotypical reversions in the sense defined by me on a previous occasion. I think that Testut (loc. cit., p. 55), in quoting the only two previously recorded cases of retro-clavicular supernumerary muscles (Weber's and Tait's), strikes the correct keynote of their morphological significance, when he says, regarding Tait's case: "If this muscle had had a few centimeters greater length it would have become attached to the upper border of the scapula, and we would have changed its name and place in the classification; it would have been a sterno-chondro-scapularis."

REPORTED INSTANCES OF UNION OF THE STERNO-CLEIDO-MASTOID AND TRAPEZIUS

In conclusion it may be well to consider that some reported instances of more or less complete union of the sterno-cleido-

mastoid and trapezius may find their explanation in the persistence of portions of this same muscular plane and their secondary fusion with the muscles named near their clavicular attachment.

Thus Quain ("Anat. of the Arteries," p. 186) describes a muscular fasciculus which detaches itself from the anterior border of the trapezius and joins the sterno-cleido-mastoid, passing above the subclavian artery. Testut quotes this instance as representing a first stage in the fusion of the two muscles.

Davies-Colley encountered in several cases a distinct muscular fasciculus which left the anterior border of the trapezius, crossed the subclavian triangle diagonally and inserted into the clavicle underneath the sterno-cleido-mastoid. In some instances the descending branches of the superficial cervical plexus were placed behind this fasciculus.

In the case of the muscle here reported the supra-clavicular nerves descended to the thorax between the clavicle and the abnormal muscle. The connection of the two extremities of the muscle with the deep surface of the clavicular head of the sterno-cleido-mastoid and the trapezius was very intimate. A firm fibrous fusion of its sheath with the fascia of these muscles made a complete exposure from behind and careful dissection necessary in order to demonstrate the independence of the muscular fibres and their true insertion into the clavicle. When first encountered *in situ* from in front the case was reported as a muscular band joining the anterior edge of the trapezius to the deep surface of the clavicular head of the sterno-cleido-mastoid. It is conceivable that further reduction of the intermediate portion of the typical sterno-chondro-scapularis, with loss of the secondary clavicular attachment seen in our case of *supraclavicularis proprius posterior* might leave a muscular fasciculus apparently extending between the deep surfaces of trapezius and sterno-cleido-mastoid, and thus give rise to the reports of partial fusion of these muscles.

PLATE IV.

PLATE IV.

With the case here recorded it is possible to present the entire group of retro-clavicular supernumerary muscles in their mutual relationship and in their common reference to the potential parent muscular system of the mammalian sterno-chondro-scapularis. Schematically this can be done as indicated in the plate IV.

Fig. 1 represents the typical mammalian sterno-chondro-scapularis, encountered as already stated in the human subject, as an occasional variation.

Fig. 2 corresponds to the retro-clavicular muscle as described by Weber and Tait; the "*M. sterno-chondro-clavicularis posterior*" results from the sterno-chondro-scapularis by loss of the scapular attachment and transference of the distal insertion to the clavicle.

Fig. 3 may be taken as illustrating Hyrtl's variations of the usual M. sterno-clavicularis in which the sternal attachment of the slip is beginning to show a tendency to migration laterad towards the clavicle.

Fig. 4 shows a theoretical combination between the sterno-clavicularis posterior and the occasional scapulo-clavicularis or coraco-clavicularis. These two muscular slips would appear respectively as the proximal and distal segments of a typical sterno-chondro-scapularis whose intermediate portion had disappeared.

In Fig. 5 is shown the reverse condition, illustrated by the case reported in this paper. In place of the disappearance of the intermediate segment of the sterno-chondro-scapularis, which produced in Fig. 4 two muscles, a sterno-clavicularis and a scapulo-clavicularis, we have in our instance the converse of this. The central part of the typical sterno-chondro-scapularis persists, while the loss of the proximal sternal and distal scapular attachment leaves us with a retro-clavicular muscle, fixed at both extremities to the clavicle, and hence properly designated as the "supraclavicularis proprius posterior." This muscle, as well as the remaining members of the retro-clavicular groups are, therefore, to be regarded as myotypical reversions, in the sense that they represent the occasional development of portions of a common ancestral mammalian muscular plane, which in many living forms finds its expression in the sterno-chondro-scapularis.

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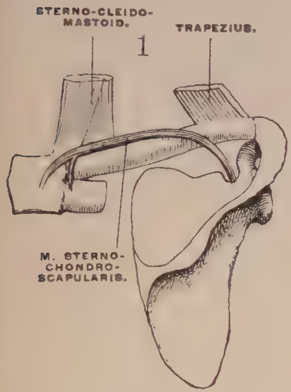
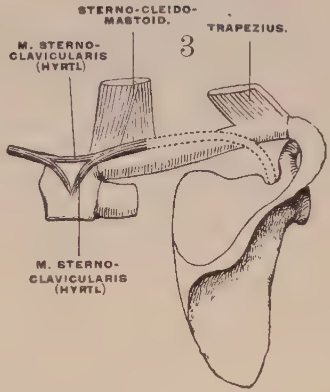
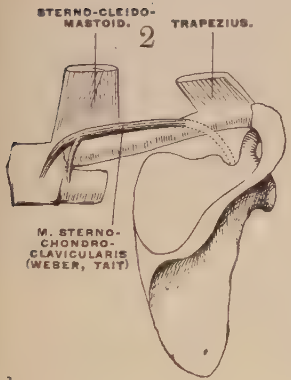

STERNO-CLEIDO-
MASTOID.
TRAPEZIUS.
M. STERNO-
CHONDRO-
SCAPULARIS.

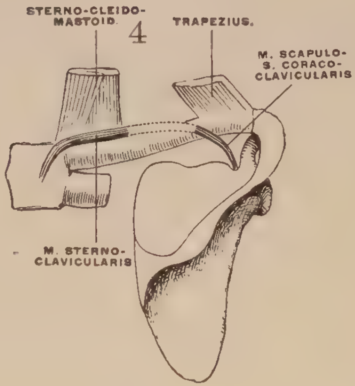
3


STERNO-CLEIDO-
MASTOID.
TRAPEZIUS.
M. STERNO-
CLAVICULARIS
(HYRTL)
M. STERNO-
CLAVICULARIS
(HYRTL)

2


STERNO-CLEIDO-
MASTOID.
TRAPEZIUS.
M. STERNO-
CHONDRO-
CLAVICULARIS
(WEBER, TAIT)

4


STERNO-CLEIDO-
MASTOID.
TRAPEZIUS.
M. SCAPULO-
S. CORACO-
CLAVICULARIS
M. STERNO-
CLAVICULARIS

5

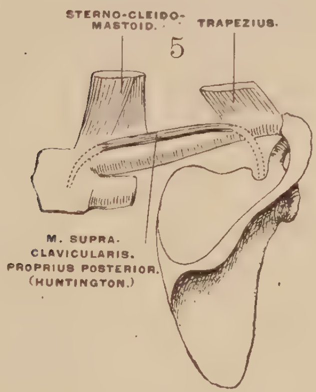

STERNO-CLEIDO-
MASTOID.
TRAPEZIUS.
M. SUPRA-
CLAVICULARIS.
PROPRIUS POSTERIOR.
(HUNTINGTON.)

PLATE V.

Annals N. Y. Acad. Sci., XIV, July 6, 1901—5


Clavicular attachment of Trapezius.
M. Supra-clavicularis proprius posterior.
Clavicular head of Sterno-cleido-mastoid.
Clavicular attachment of Pectoralis major.

[Annals N. Y. Acad. Sci., Vol. XIV, No. 3, pp. 67–68, July 6, 1901.]

DISCOVERY OF A MASTODON'S TOOTH AND THE REMAINS OF A BOREAL VEGETATION IN A SWAMP ON STATEN ISLAND, N. Y.

By Arthur Hollick

(Read Nov. 13, 1899)

In the Moravian Cemetery at New Dorp, Staten Island, was a swamp, which, until the past summer, was rather a conspicuous feature, by reason of its quaking margin of peat and sedges, with a pool of dark coffee-colored water towards the center. It occupied a depression in the moraine, at a distance of about 1,200 feet from the margin and at an elevation of about 120 feet above tidewater. The superficial area of the swamp was about 3,500 square feet and the pool of water would fill up and overflow in time of rains and become almost or completely dry in periods of drought.

In the recent development of the cemetery it was decided to drain off the water, dig out the mud, and allow the depression to fill up again as a pond. It was during the progress of this work that the discoveries here recorded were made.

The surface deposit was found to consist of a fine moss peat and a coarse peat composed of all kinds of swamp vegetation, extending out to the margin of the pool, while below this and forming the bottom of the pool was a black organic mud, such as may be seen in almost any swamp where decaying vegetation has accumulated. Below this the deposit was a fine sandy silt, distinctly stratified, the layers following the general contour of the depression, thicker towards the middle and thinning out at the edges. The general shape of the depression is roughly pyramidal, with steeper sides on the north and east than on the south and west. The deepest part is in the northeast angle, where the entire deposit was about 25 feet in thickness. All this deposit has been taken out and the sides and bottom of the depression are now exposed to view.

The first thing which attracted my attention was a number of logs and branches in the upper part of the silt, beginning at a depth of about 5 feet from the surface. There was nothing in connection with these to indicate that they were anything more than the remains of a comparatively recent forest growth. Below this, however, at a depth of about 8 feet, were a number of layers, aggregating about 2 feet in thickness, containing a large number of small cones and twigs. There are no coniferous trees now growing in the vicinity and no record of any in recent years so that these were manifestly the remains of a forest growth which antedated the one now growing there and a subsequent careful examination and comparison of the cones showed them to belong to the white spruce (*Picea Canadensis* (Mill) B.S.P.)—a tree of northern range, which does not now extend farther south than northern New England and the Adirondacks —and this fact naturally led to the conclusion that at least the lower portion of the deposit was of Quaternary age.

On inquiry of the superintendent of the cemetery, Mr. N. J. Ostrander, information was subsequently obtained to the effect that "some bones" had been dug out by one of the workmen, at a depth of about 23 feet, and these were very kindly turned over to me. They proved to be the broken pieces of a mastodon's molar and the Quaternary age of the deposit was established beyond question and inasmuch as it was in a morainal basin it must all have been post-morainal in age.

The indications are that a pond was formed in the depression immediately after the recession of the ice sheet and that this pond was a receptacle for silt, dust and decayed vegetation ever since; the accumulations finally filling it up and converting it into a swamp, with a little pool of casual water remaining in the middle.

Incidentally it may also be worth recording, that a considerable amount of charcoal and charred wood was found in connection with the cones, near the northeastern side, which fact might indicate the presence of man at the time this portion of the deposit was laid down.

[ANNALS N. Y. ACAD. SCI., Vol. XIV, No. 4, pp. 69–84, July 2, 1901.]

OBSERVATION AND EXPERIMENT[1]

BY R. S. WOODWARD

The near coincidence of this anniversary meeting of the Academy with the end of the nineteenth and with the beginning of the twentieth century imposes peculiar and quite unexpected restrictions in the way of freedom of choice of a fitting subject for an address. Naturally one would like to pass in review some of the brilliant achievements of science in the past century, and perhaps forecast the still more brilliant advances that may be expected to mature in the present century. Especially one might feel tempted to present a semi-popular inventory of the more striking or recondite scientific events with which he is particularly familiar. But all this and more, strange as it may seem, has been done, or is being done, by the public press. Specialists in almost every branch of science have been employed to expound and to summarize the discoveries, the theories, and the useful applications which have rendered science, by common consent, the most important factor in the civilization of the nineteenth century. Statesmen, philosophers and divines are likewise sounding the praises of science and the scientific method with a warmth of recognition and with a stamp of approval which tend to make one who is old enough to have lived in the pre-scientific, as well as in the present epoch, feel as if a millennium were close at hand. Indeed, such a wealth of good scientific literature is just now thrust before us and such a wealth of praise is just now bestowed on scientific achievement that the modest man of science must hesitate before adding a word to that literature or a qualification to that praise.

[1] Address of the President of the New York Academy of Sciences, read before the Academy on February 25, 1901.

The requirements of official position are remorseless, however, and one must speak his thought although silence with respect to science may appear to be the most urgent need of the hour. In view of these circumstances, it seems best to avoid topics of current interest and to invite your attention to a brief consideration of the elements which lie at the basis of scientific investigation and scientific progress. A recurrence to the slow and painful beginnings of knowledge and the first principles evolved therefrom is always instructive; and it is especially fitting at a time, like the present, when the ardor of research is somewhat in danger of the sedative influences which spring from the popular glorification of triumphant successes.

The fundamental data from which all scientific knowledge grows are furnished by observation and experiment. After these come the higher steps of comparison, hypothesis, and finally the correlation and unification of phenomena under theory. Even pure mathematics, though long held apart from the other sciences, must be founded, I think, in the last analysis, on observation and experiment.

Of the infinite variety of phenomena, which appeal to our senses, some, like those of sidereal astronomy, are subject, in the main, to observation only; while others, like those of terrestrial physics, chemistry, and biology, are subject to both observation and experiment. All phenomena are more or less entangled. They point backward and forward in time; any one of them appears and disappears only in connection with others; and the record any one of them leaves is known only by its interaction with others. Out of this plexus of relations and interrelations it is the business of science to discover the conditions of occurrence and the laws of the continuity. Happily for man, although the ultimate complexity of phenomena is everywhere very great, it is frequently possible to discern those conditions and occasionally possible to trace out those laws. But the results we reach are essentially first approximations, depending, in general, on the extent to which we may ignore other phenomena than those specially considered. In fact, a first step towards the solution of a problem in science consists

in determining how much of the universe may be safely left out of account. Thus the method of approximating to a knowledge of the laws of nature is somewhat like the method of infinite series so much used by mathematicians in numerical calculations; and as it is a condition of success in the use of such series that they be convergent rather than divergent, so is it an essential of scientific sanity that the mind be restricted by observed facts rather than diverted by pleasing fancies.

The prime characteristic of the kind of knowledge that leads up to science is its dependence on facts which are permanent and hence verifiable. In the course of the progress of our race there have been certain luminous epochs during which observers and experimentalists have revealed more or less of such knowledge. These epochs have been followed, generally, by others of camparative dullness, or positive darkness, during which fact has been replaced by fancy and what is permanent and verifiable has been eclipsed by what is ephemeral and illusory. It is my purpose to-night to recall some of the principal events of these epochs, and to enforce, as well as I may, the great lesson they seem to teach us, namely, that science can be maintained only, and can be advanced only, by a constant appeal to observation and experiment.

As we look out on the universe about us the most striking phenomena visible are those which belong to what Galileo and his successors have fitly called "the system of the world." The rising and setting of the sun and moon; the majestic procession of the seasons; the splendid array of the stars in the heavens; the ebb and flow of the sea; and the never-ending variety from wind and weather, need only to be mentioned to enable us to understand why astronomy is at once the oldest and one of the most highly developed of the sciences. No classes of phenomena are so obvious, so omnipresent, and so enduring. They have furnished the symbols of continuity and permanence for all languages in all historic times. The "fixed stars," for example, are in fact, as well as in fiction, our standards of reference in the reckoning of time and space; for are not "Sirius

and Orion and the Pleiades," as Carlyle has remarked, "still shining young and clear in their courses as when the shepherds first noted them on the plains of Shinar"?

But before astronomy there were mythology and astrology, and we may well marvel how it has been possible, even after the lapse of twenty odd centuries, to educe the orderly precision of science out of the complicated miscellany of fiction, fact, religion, and politics bequeathed to our era by the fertile imaginations of our distinguished ancestors. What, for example, could be more confusing than the paleontological jungle called the stellar constellations, with its gods and goddesses; with its dogs, lions, bears and fish, great and small, northern and southern; with its horse, whale, and goat; and with the slimy forms of serpents intertwining them all?

Although it is impossible to set any date for the emergence of astronomy out of mythology and astrology, the epoch of Hipparchus undoubtedly is the earliest one of conspicuous advances known to us. This epoch, which may be called also the epoch of the Alexandrian school of science, extends from about 300 B.C. to about 150 A.D. It is distinguished by the remarkably perfect work in pure geometry of Euclid and Apollonius, and by the still more noteworthy work of Archimedes in laying the foundations of statics and hydrostatics; it comprises the measurements according to correct principles of the obliquity of the ecliptic and the dimensions of the earth by Eratosthenes; it includes the observations of the sun, moon, stars and planets collected by Aristyllus and Timocharis and later turned to so good account by Hipparchus; it embraces the work of Aristarchus, who maintained the heliocentric theory of the solar system and who was the first to attempt a measure of the dimensions of that system by means of the fine fact of observation that the earth, sun and moon form a right triangle with the right angle at the moon when the latter is in dichotomy—or when its face is just half illuminated; and finally it includes the work of Ptolemy, a worthy disciple of Hipparchus, whose Almagest has come down to our own time.

From the observational point of view we must rank the prin-

ciples with respect to fluids at rest discovered by Archimedes as amongst the capital contributions to the science of all times; for while his successors, of the last two centuries especially, have added to hydromechanics the large and vastly more difficult branch of hydrokinetics, they have found no change essential in his laws of hydrostatics.

Equally important, also, in its far-reaching connections was the work of Eratosthenes in determining the size of the earth. This work required an hypothesis as to the shape of the earth and appropriate observations. Supposing the earth to be spherical, an assumption which Eratosthenes knew well how to justify, he saw that to determine its size it is only necessary to apply the rule of three to the measured length of an arc of a meridian and to the measured difference of the latitudes of the ends of such arc. He observed that at the city of Syene, which is about 500 miles south of Alexandria, the sun shone vertically downwards into deep wells at noon on the day of the summer solstice, showing thus that at that place and time the sun was in the zenith. On the same day at Alexandria he observed, by means of the gnomon, that the sun at noon was south of the zenith by one-fiftieth of a circle, or $7^{\circ}.2$. The distance between the two points was found by the royal road masters of the country to be 5,000 stadia, thus giving for the complete circumference of the earth 250,000 stadia. Although the measurements thus made by Eratosthenes were very crude and undoubtedly subject to large errors, we see in them the beginnings of some of the most refined geodetic operations of the present day. Unfortunately for us, also, the measurement of the distance is expressed in a unit whose relation to modern units is only roughly known.[1]

But commendable as was the work of his predecessors and contemporaries, the work of Hipparchus rises to a still higher

[1] As illustrating the slow growth of ideas with respect to precision, it may be related that when the Arabians, in the ninth century undertook, for the same purpose, the measurement of a meriodinal arc on the plain Singiar, in Mesopotamia, they were not more successful in preserving for posterity the standard of length used by them. This standard is said to have been the "black cubit, which consists of 27 inches, each inch being the thickness of six grains of barley."

plane. He was an observer and a theorist of the highest type, being able at once to collect facts and to interpret their relations, and he deserves to be ranked among the great astronomers of all times. He was the first to clearly appreciate the value of a catalogue of the fixed stars and constructed one giving the relative positions of 1,080 stars. He observed with surprising precision the interval of the tropical year; he made the first tables of the sun and moon; he discovered the remarkable fact of the precession of the equinoxes; and he thus early led the way to the great advances of modern times.

The peculiar merit of the work of Hipparchus lies not alone in the fact that he saw how the apparent motions of the heavenly bodies may be determined by observations, but also in the fact that he saw how these motions may be determined by a very small number of appropriate observations. Thus, for example, the interval from the vernal equinox to the summer solstice and the interval from the latter to the autumnal equinox sufficed to give him a close approximation to the apparent motion of the sun; while the records of a few eclipses of the moon enabled him to deduce a closely correct value of the precession of the equinoxes, that shifting of the line of intersection of the equator and the ecliptic which goes on so slowly that an interval of nearly 26,000 years is required for a complete circuit.

Hipparchus may be called the founder of the geocentric theory, since he demonstrated the accordance of the phenomena known to him with that theory. The fact that this theory is false detracts little from his merits; for the sole requisites of a good theory are simplicity of statement and conformity with observation. We now know, indeed, that mechanical phenomena are, in general, susceptible of multiple interpretations, and that observation must decide which of them is to be preferred.

The method which Hipparchus used to measure the sun's apparent motion among the fixed stars is very noteworthy, especially when we consider the utter lack of effective instruments in his time. If the sun moves regularly about the earth, as first supposed by Hipparchus, it ought to return at any epoch, as that of an equinox, to the same position among the

fixed stars. Imagine a line drawn at the time of the vernal equinox, say, from the center of the earth to the center of the sun. This line prolonged will pierce the celestial sphere in two points, and if either point can be located, the position of the sun with reference to the stars becomes known. Hipparchus fixed this position by noting the location among the stars of the center of the shadow cast by the earth at the times of eclipses of the moon. By a comparison of his own observations of such eclipses with those made by his predecessors he was able to determine the apparent motion of the sun with reference to the stars, or what we now know to be the motion of the equinoxes with reference to the stars. To establish this fact of precession from such meager observations was a great step; and it seems not a little singular that a phenomenon so striking should not have led to speedy investigations for its source. But about eighteen centuries elapsed before Newton clearly visualized the mechanical interpretation of this phenomenon, and it was only after an additional half century that the interpretation was fully worked out by d'Alembert.

How rapidly the spirit of science dies out when its devotees cease to observe and experiment is shown by the failure of the "Divine School of Alexandria" to maintain the high standard set by Hipparchus. His immediate successors became at best only commentators. They wrote much but observed little; and it does not appear that any of them attempted even to verify the remarkable discoveries of Hipparchus during the two hundred and fifty years which elapsed between the period of his activity and the advent of his worthy disciple and expounder Ptolemy.

It is to the work of Ptolemy chiefly that we owe our knowledge of the discoveries and theories of the Hipparchian epoch. His treatise on the "Great Construction," the Megiste Syntaxis, or the Al Magisti and hence Almagest of the Arabians, is the earliest of the great systematic treatises on astronomy. It is in this work that the theory of eccentrics and epicycles of Hipparchus is explained and elaborated, and it is this work which has given the name of Ptolemy rather than that of his

acknowledged master to a system of the world which dominated scientific thought for nearly fifteen hundred years.

The period during which the observations and researches of Ptolemy were carried on is commonly referred to in history as extending from the reign of the emperor Hadrian to that of Marcus Aurelius. Thus, while Ptolemy was an Egyptian by birth, the fact that he was permitted to pursue his astronomical studies under the empire helps to some extent to relieve the Romans of the charge that they were, as regards science, the most ignorant people of antiquity. But the gravity of that charge is only palliated by the work of Ptolemy, for he left no successors. Roman astronomy did not rise above the level of astrology; the spirit of scientific enquiry gave way to speculation and declamation; and the long night which followed was not broken until the dawn of the epoch of Galileo — the modern epoch, whose advances have been founded on observation an experiment.

If astronomy is preëminent among the sciences for its dependence on observation, chemistry and physics are equally preëminent for their dependence on experiment. This difference in methods of investigation between the former and the two latter sciences is a difference imposed by the circumstances that astronomy deals chiefly with objects at long range while chemistry and physics are concerned with objects near at hand. It seems not a little singular, however, at first thought, that progress in the development of knowledge concerning the behavior of distant bodies should have been almost as rapid up to the present time as the development of knowledge concerning bodies much more familiar and accessible to us.

Chemistry and physics, like astronomy, had their forerunners in mythological follies and extravagances. Semi-civilized and civilized man required a long time after he had learned how to talk and to write well, after he had founded states and constructed systems of philosophy and religion, before he could reason rationally and successfully with respect to the commonest material things about him. Thus, chemistry was long obscured by merely verbal speculations on the "four elements, earth, air, fire and water" or on the "three elements, salt, sul-

phur and mercury"; while the beginnings of physics were perhaps even more clouded by the fantastic unrealities of fertile but unchecked imaginations.

But man early learned to measure the value of chemistry by the "gold standard." It is hinted, in fact, though without adequate evidence, that the Golden Fleece of the Argonautic expedition was a manuscript containing valuable secrets of the chemist's art; and Suidas, of the eleventh century, to whom the word chemistry is attributed, relates that Diocletian, fearing that the Egyptians, by reason of their knowledge, might become rich and restive, ordered, in true Roman fashion, that their books on chemistry should be burned. The thirst for gold assisted also in the development of alchemy, which flourished from the eleventh to the fifteenth century, especially, and has had not a few adherents, it would seem, during all the centuries down to and including the one just past. The philosopher's stone was almost universally believed to be a real agent in medieval times; and this strange fiction also has its survivals in the "mad stones," "moon stones," "lucky stones," and other "charms" whose use even at the present time is not uncommonly justified by the wise saying that "there may be something in them."

The difficulty in getting the human mind started with the elements of physical science is well illustrated, likewise, by the superstitious rubbish that encumbered the early progress of knowledge concerning magnets. They were endowed with imaginary qualities far more wonderful than subsequent observation and experiment have disclosed. It was believed, for example, that they would cause some diseases and cure others; that they were effective as love philters; that they would lose their properties when rubbed with garlic (which seems not so unlikely), but that a bath in goat's blood would readily counteract this destructive effect. And in this case, also, as with alchemy and the philosopher's stone, it is to be noted that such crude notions of the phenomena of matter find their survivals at the present day in a wide acceptance of the unverified efficacy of "magnetic healers" and "electric belts," and in the ease with

which capitalists can be persuaded to invest in a "Keely motor" or in anything that promises the marvelous.

With the decline of alchemy the field for chemistry shifted somewhat. Not unnaturally, since most chemists were also physicians in those days, a knowledge of the chemical properties of substances came to occupy a prominent place in the physician's art. Thus Paracelsus in the sixteenth century, cutting loose from the teachings of Aristotle and Galen, boldly asserted that the true use of chemistry is not to make gold but to prepare medicine; and he and his follower Van Helmont, in addition to attaining fame for skill in compounding remedies, were amongst the first to appreciate the true import of the processes of analysis and synthesis which came to be called in their day the spagyric art. Then followed the doctrine of the mutually neutralizing substances, acid and alkali; the fruitful hypothesis of elective attractions or affinities; the ingenious, if erroneous, theory of phlogiston, and the more permanent theory of oxygen. All these led up through more and more searching experimentation to the first great epoch in the history of chemistry—the epoch of Lavoisier.

Among the early workers in the century preceding the epoch of Lavoisier the names of Becher and his disciple Stahl deserve especial mention, not only by reason of their introduction of the theory of phlogiston, but also by reason of their enthusiastic and steadfast devotion to science without hope of pecuniary reward. In his remarkable treatise entitled "Physica Subterraneæ," published in 1681, Becher defends the scientific pursuit of chemistry as not less worthy of attention than philosophical and theological studies. He insists especially on the need of careful observations and on the necessity of constantly verifying theory by experiment. With true scientific enthusiasm he describes the chemist as one willing to work amid the flames and fumes, and, if need be, the poisons and poverty of the laboratory. He has no patience with the charlatans, of which it appears there were still many in his day, who are looking chiefly for ways and means of extracting the precious from the baser metals. As for himself he says, "My kingdom is not of this

world. I trust that I have got hold of my pitcher by the right handle—the true method of treating this study; for the pseudo-chemists seek gold, but the true philosophers, science, which is more precious than any gold."

It is a peculiarly noteworthy fact that while much attention was given to chemistry during ancient and medieval times, comparatively little attention was given to the other branches of physical science. Our knowledge of heat, light, electricity, and magnetism is almost wholly a development of modern times. The Greeks were acquainted with a few of the more elementary phenomena of electricity and light; and Ptolemy and Alhazen came near discovering the law of optical refraction; but there was no contribution made to either of those physical sciences comparable with the discoveries of Hipparchus in astronomy until the epoch of Galileo. What a marvelous increase in the rate of scientific progress began with this epoch is shown on nearly every page of the subsequent history of science. Galileo and his contemporaries may be said to have established the methods of observation and experiment. Their systematic application has borne fruit in every science. Almost every step forward has led to additional advances, until now each of the physical sciences has its wide array of determinate facts correlated under a great theory. In the domain of light, for example, the only solid contribution of the ancients is the obvious fact of radiation in straight lines. After nearly sixteen hundred years of our era had elapsed, there came Galileo's invention of the telescope, and about the same time Snell's discovery of the law of refraction. To the telescope were soon added the microscope and the camera obscura. Then followed Newton with explanations of the rainbow, dispersion, and kindred phenomena; Hooke with his discovery of the colors of thin plates; Dolland with the combination of two lenses to produce achromatism; and Huygens with his discoveries and explanations of double refraction and polarization; while in the meantime Roemer had measured the velocity of light. All these accessions crowded one another so closely that the emission theory of Newton and the undulatory theory of Huygens followed almost as a matter

of necessity. The battle royal of these two rival theories, as you know, lasted for nearly a century until the emission theory, by the sheer force of critical observations and experiments, was displaced by the undulatory theory through the brilliant researches of Young and Fresnel.

When we turn from the physical to the geological and biological sciences, the same lessons of the necessity and the efficiency of observation and experiment are still more strikingly apparent. For although geology and biology are the youngest of the grand divisions of science, they have accomplished more than all others toward giving man a proper orientation with respect to the rest of the universe. Geology as we now understand the term is but little more than a hundred years old, and biology in the sense now attached to the word, is less than fifty years old. Nevertheless, these sciences have been the chief contributors to the doctrine of evolution, which, in view of the wide range of its applicability, must be regarded as the most important generalization of science.

It is a singular circumstance, however, considering the early advances made in the interpretation of the phenomena of astronomy, that the equally ubiquitous and far more accessible phenomena of geology and biology should have been so tardily investigated. The cause of this delay seems to lie in the fact, not without examples in the present day, that our remote ancestors had the habit of constructing their theories first and making their observations, if at all, afterwards ; and in the cases of geology and biology they were so well satisfied with their theories that the trouble of making observations was for a long time dispensed with.

We of the present day have no right, perhaps—and I for one would not be disposed to use such a right if conceded—to blame our predecessors for the narrow, and in some instances crooked views they held with regard to these subjects. But on the other hand, we shall fail, I think, to make proper use of our opportunities if we do not learn speedily to conduct scientific investigations in the future so as to avoid such colossal blunders as mar the history of geology and biology from its beginnings down almost to our own time.

As an illustration of the blunders referred to I may cite the profound reluctance even of eminent men of science to accept the plainest teachings of observation with respect to geological time up to the middle of the century just passed. Not until Lyell the great champion of uniformitarianism, as opposed to catastrophism, had published his "Principles" (1830) did scientific opinion show a tendency to accept the fact of the hoary age of the earth everywhere attested by the rocks in her crust.

And what a storm of opposition and condemnation, amounting almost in some cases to social ostracism, was visited by the very "salt of the earth" against those who ventured during the sixties and the seventies of the last century to consider favorably the arguments of the "Origin of Species"! All this has about it the freshness, and possibly the pain and the humor, of personal recollection for those of us who are old enough to have lived in two epochs. That a mistake of this sort could have been made thirty or forty years ago seems strange enough in these peaceful times of ours. But while we may properly let the recollection of the storm and stress of this earlier period fade away, the moral of the conflict should be held up as a permanent warning to scientific as well as unscientific men; for no episode in the previous experience of the race demonstrates so clearly the sources of knowledge and the methods of attaining it.

As a final illustration of the validity of my thesis I would invite your attention to one of the most instructive and beneficent of the many brilliant biological researches of recent times. No one who has suffered from repeated attacks of intermittent fever and has survived the ravages of the materia medica, can fail to take a lively interest in the wonderful progress made during the last twenty years towards a definite knowledge of the natural history of that disease. Nor can any one interested in the general aspect of science fail to see in the investigations leading up to this progress some of the finest examples of the scientific method.

It would appear that malarial fever has been one of the com-

monest disorders, in certain localities, with which man in his struggle for existence has had to cope; and before the discovery of the properties of Peruvian bark it must have been a very serious affliction by reason of its secondary if not by reason of its primary effects. The symptoms, course, and distinguishing characteristics of the disease, as well as the remedies therefor, were long known, however, before it was suspected that the mosquito had anything to do with its dissemination. Bad water, foul air, and sudden or extreme changes of temperature were supposed to be promoting causes. The dampness of marshes, swamps, and other areas holding stagnant water was held to be an especially common attendant, if not inducing, condition. There was, indeed, no lack of acute and painstaking observations and no lack of ingenious and well-supported hypotheses with regard to this widely prevalent but obscure disorder. The details of its diagnosis, prognosis, nature, and causation as laid down in the medical manuals of a few decades ago, are particularly interesting and instructive reading now in view of recent developments. For example, Hartshorne in his "Essentials of the Principles and Practice of Medicine," published in 1871, gives the following explanations:

"No disease has ordinarily so regular a succession of definite stages as intermittent fever, namely the cold, the hot, and the sweating stage." * * * "Upon the origin of malarial fevers," he adds, "the following facts seem to be established: 1. They are reasonably designated as autumnal fevers, because very much the largest number of cases occur in the fall of the year. Spring has the next greatest number of cases. 2. They are always strictly localized in prevalence. 3. They never prevail in the thickly built portions of cities. 4. An average summer heat of at least 60° F. for two months is necessary for their development. Their violence and mortality are greatest, however, in tropical and subtropical climates. 5. They prevail least where the surface of the earth is rocky; and most near marshes, shallow lakes and slow streams. The vicinity of the sea is free from them, unless marshes lie near it. 6. The draining of dams or ponds, and the first culture of new soil, often originates them.

7. Their local prevalence in the autumn is always checked by a decided frost."

Here we have the facts with regard to the symptoms and cause of the disease stated with a clearness and a conciseness that could hardly be surpassed. But the real cause of the malady eluded the insight of the discriminating observers who collected those facts. A quite different class of facts required consideration. It was essential to concentrate attention on the pathological aspects of the enquiry. As to the nature of the disease Hartshorne writes, with commendable caution, "It is only possible to speculate at present. It is most probable that ague is a toxemic neurosis. The importance of the blood change attending it is shown by the disintegration of the blood corpuscles, and deposit of pigment in various organs." This destruction of the blood corpuscles was the critical point on which the investigation turned. About 1880, Laveran, a French army surgeon, discovered the destructive agency in a minute parasite, one of the protozoa, which takes up its residence in, and then ungratefully enough, destroys our red blood corpuscles. What a splendid problem was presented by the facts thus brought to light! The exquisite refinement of the researches which followed may be inferred when we reflect on the minuteness of an organism which can work out a part of its life history within blood corpuscles so small that four to six millions of them find plenty of room in a cubic millimeter. But stranger still is the fact established within the past year or two that the mosquito plays the rôle of an intermediary host and transmits the parasites to us while feasting upon our blood. The details of this remarkable discovery need only be alluded to here, for they have been so recently explained by the experts participating in them that their essential features are a part of popular information. Suffice it to remark that they show how we may secure almost complete immunity from malarial fevers at no distant day.

Thus, in whatever direction we look for the sources of scientific progress, the same elementary methods of advancement are found to be effective. Whether we consider the dimensions

of the solar system or the distances between the molecules of a gas; whether we seek the history of a star as revealed by its light or the history of the earth as recorded in its crust; whether we would learn the evolution of man or the development of a protozoön; whether we would study the physical or chemical properties of the sun or the corresponding properties of a grain of sand; in short, whether we turn to the macrocosm or to the microcosm for definite, verifiable knowledge, it is found to originate in and to advance with observation and experiment.

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